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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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See page 17. 8305

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See page 15. 7454

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7768
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See Full Page Advt., page 78, Jan. 9.

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Forgings, Castings, Bars, Sheets, Wire, Tubes.
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See Full Page Advertisement, Jan. 9

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See half-page Advert, last week and next week. 7536

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Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 7840
See half-page Advertisement page 99, Dec. 26.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

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The National Foremen's ASSOCIATION OF THE ENGINEERING AND ALLIED TRADES.

(Registered under the Trade Union Act.)

An Association specially formed to look after the interests of Foremen on their Supervisory Capacity. C 508

All communications to— H. W. RHID, General Secretary. Head Offices— 81, High Holborn London, W.C.1.

The Concrete Institute.

AN INSTITUTION FOR STRUCTURAL ENGINEERS, ARCHITECTS, &c.

EXAMINATIONS for GRADUATESHIP and for ASSOCIATE-MEMBERSHIP will be held at the offices of the Institute on 13th and 14th MAY, 1920. Forms of application and full particulars may be obtained from the SECRETARY, Denison House, 296, Vauxhall Bridge Road, London, S.W. 1. C 468

Mr. William Stead, M.I.M.E., M.I.E.E.,

has OPENED an OFFICE in Manchester at DUCHY CHAMBERS, 4, CLARENCE STREET, ALBERT SQUARE,

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Mr. Stead has a wide experience in the utilisation of Waste Gases from Blast Furnaces and Coke Ovens, their cleaning and subsequent use for Power and Heating purposes; also the utilisation of Waste Heat from Furnaces, etc., in Boilers for Steam raising.

He has an extended experience of 20 years as a designer, manufacturer and user of all types of power plant, and undertakes their regular inspection, also valuations, and the preparation of Specifications, Plans, and Estimates for new work, and alterations and additions to existing works. C 838

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TENDERS.

COUNTY BOROUGH OF WEST HAM.

REFUSE DESTRUCTOR.

The Council hereby invite

Tenders for the Supply and

ERECTION of a REFUSE DESTRUCTOR and STEAM-RAISING PLANT in connection with the Electricity Generating Station, Quadrant Street, Canning Town.

White Plan, Specification, Form of Tender, and further particulars may be obtained at the Office of the Borough Engineer, Town Hall, West Ham, E. 15, upon payment of a deposit of £1, which will be returned upon receipt of a *bona fide* Tender.

NOTE.—No Tender will be considered unless the same is delivered at the Office of the Town Clerk, Town Hall, West Ham, E. 15, in the envelopes supplied, by registered post, not later than 4 o'clock p.m., on Tuesday, 24th February, 1920.

The Council do not bind themselves to accept the lowest or any Tender. The Contractor will be required to enter into a bond, with one surety, for the due performance of the Contract, and no work will be ordered under the Contract until such bond has been duly executed.

The Contractor, whose Tender is accepted, and with whom a Contract is entered into, will be required to pay the whole of his workmen such rate of wages, and observe such hours of labour, as are recognised by the Workmen's Trade Unions, and shall not assign, nor under-let, or make a sub-contract with any person or persons for the execution of any part of such work. In the event of any breach of such agreement the Council will enforce the penalty clause in its entirety.

By Order of the Council,
GEORGE R. HILLBARY,
Town Clerk.
Town Hall, West Ham, E.
2nd January, 1920. C 715

AUCKLAND HARBOUR BOARD, NEW ZEALAND.

Tenders are Invited for the

SUPPLY and DELIVERY of TWELVE (12) Five-ton (and alternatively for Three-ton) SEMI-PORTAL, BALANCED-JIB, LEVEL-LUFFING ELECTRIC CRANES.

SPECIFICATIONS can be obtained at the Office of Board's Agents on payment of a deposit (returnable) of Two Guineas. Drawings can be seen only at the Office of the Board's Agents:

Messrs. W. & A. McARTHUR, LTD.,
13-19, Silk Street,
Cripplegate, London, E.C. 2.

Tenders to reach Auckland by noon on Sept. 1st, 1920, addressed, The CHAIRMAN, Harbour Board, Auckland, New Zealand. C 444

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED,

are prepared to receive

Tenders for the Supply of:—

STEEL BOILER PLATES.

Specifications and Forms of Tender may be obtained at the Company's Offices.

Tenders addressed to the Chairman and Directors of the South Indian Railway Co., Ltd., marked "Tenders for Steel Boiler Plates," must be left with the undersigned not later than Two p.m. on Wednesday, the 4th February, 1920.

A charge, which will not be returned, will be made of 10s. for each copy of the Specification.

Copies of the drawings may be obtained at the office of ROBERT WHITE, Esq., M.Inst.C.E., Consulting Engineer to the Company, 3, Victoria Street, Westminster, S.W. 1.

By Order,
W. B. REYNOLDS,
for Managing Director.

Finsbury Pavement House,
London, E.C. 2,
9th January, 1920. C 875

EDINBURGH CORPORATION ELECTRICITY SUPPLY.

The Lord Provost, Magistrates and Council invite

Tenders for one Overhead

TRAVELLING CRANE to Specification No. 24, Portobello Station.

Copies of the Specification, Forms of Tender and Drawings can be obtained from the Engineer, Dewar Place, Edinburgh, upon payment of a deposit of £2 2s. Additional copies of the Specification can be obtained upon payment of a deposit of £1 1s. for each copy. Deposits will be returned after receipt of a *bona fide* Tender and on return of the Specifications and drawings.

The Specification and drawings can be seen at, but not obtained from, the office of Sir ALEX. B. W. KENNEDY, 17, Victoria Street, Westminster, London, S.W. 1.

Tenders, on the prescribed form, enclosed in sealed envelope and endorsed on the outside "Electricity Supply, Tender for Specification No. 24," must be delivered at the office of the undersigned not later than 9th February, at 10 a.m.

The Council do not bind themselves to accept the lowest or any tender.

A. GRIBBON, S.S.C.,
Town Clerk.
City Chambers, Edinburgh,
12th January, 1920. C 882

METROPOLITAN BOROUGH OF HAMMERSMITH.

ELECTRICITY DEPARTMENT.

SUPPLY OF REFRACTORY MATERIALS.

The Council Invite

Tenders for the following:—

Materials required for Boiler setting and Furnace work, viz.:—

(i) Supply and delivery only of Refractory Insulating, and ordinary Brickwork, and materials; or

(ii) Supplying, as in (i), and executing the necessary work required in setting a class 38/16 Stirling Boiler; or

(iii) Executing the work, as in (ii), only, without supplying the necessary materials.

Specifications and Forms of Tender may be obtained from Mr. G. G. BELL, Borough Electrical Engineer, Electricity Department, 85, Fulham Palace Road, W. 6.

Sealed Tenders, endorsed "Tenders for Refractory Materials," must be delivered to the undersigned not later than Ten a.m. on Tuesday, 20th January, 1920.

LESLIE GORDON,
Town Clerk.
Town Hall, Hammersmith, W. 6.
6th January, 1920. C 767

G. R.

TWIN SCREW VESSELS FOR SALE.

WITHOUT RESTRICTIONS AS TO SALE ABROAD.

The Admiralty have for Dis-

POSAL H.M. TWIN SCREW VESSELS "BURY," "FAIRFIELD," "REPTON."

Boats are new and particulars are as follows:—

Length between perpendiculars ...	220 ft.
Breadth Moulded	28 ft. 6 in.
Depth Moulded to Upper Deck ...	16 ft. 3 in.
Coal carried, bunkers full	180 Tons.
Speed, full power, about	16 Knots.
Gross Tonnage, about	780

MAIN ENGINES.—Twin Screw, vertical, reciprocating triple expansion HP. cylinder 12½ in. diameter, M.P. cylinder 21½ in. diameter. L.P. cylinder 34 in. diameter by 21 in. stroke.

I.H.P.—1100 each engine, 2200 total per ship. Revolutions, 370 per minute.

BOILERS.—Yarrow, small tube type, coal fired. Two in No. each vessel.

Tender Forms with permission to inspect may be obtained from the DIRECTOR OF CONTRACTS, Admiralty, Branch 4, Room 25, Avenue House, Northumberland Avenue, London, S.W. 1.

Tenders will be received up to TWELVE o'clock noon on Monday, 2nd February, 1920. C 654

METROPOLITAN BOROUGH OF HAMMERSMITH.

ELECTRICITY DEPARTMENT.

WIRING OF SMALL PROPERTY.

The Council Desire to be

FURNISHED with PARTICULARS of WIRING SYSTEMS which Contractors are prepared to submit, suitable for property to be erected in connection with the Council's Housing Scheme.

Further particulars may be obtained on application to Mr. G. G. BELL, Borough Electrical Engineer, Electricity Department, 85, Fulham Palace Road, W. 6.

Propositions, which must be accompanied by a completely priced schedule for all necessary material, must be delivered to the undersigned, endorsed "Wiring Proposition," not later than Ten a.m., on TUESDAY, 20th JANUARY, 1920.

LESLIE GORDON,
Town Clerk.
Town Hall, Hammersmith, W. 6,
6th January, 1920. C 768

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD.

(FURNITURE SECTION.)

BAKERY OVENS FOR SALE.

Tenders for the Purchase of

the above will be received up to FRIDAY, JANUARY 30th.

DESCRIPTION.

A number of "Collins" Improved Double Decker Drawplate BAKERY OVENS (portable type), capacity of each baking chamber 10 ft. by 6 ft.

Lying at the R.M. STORES DEPOT, WEATHERLEES, RICHBOROUGH, Kent, in sections, packed in cases, &c., as delivered by the makers.

Tender Forms containing a schedule of the parts comprising an Oven and which will serve as a permit to view, may be had on application to the CONTROLLER, Furniture Section, Disposal Board, 18, Queen Anne's Gate, London, S.W. 1.

NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 3d., at all Bookstalls; or by quarterly subscription of 2s. post free, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. C 889

CITY OF EDINBURGH.

NEW PUBLIC WASHHOUSE, CAUSEWAYSIDE.

To LAUNDRY ENGINEERS, and others.

The Corporation invite

Schemes and Tenders from

Laundry Engineers and others for the Engineering Equipment of a new Public Washhouse to be erected at Causewayside, including new Steam Boiler and other relative plant, all in accordance with Plans and Specifications prepared by the City Architect, Mr. JAMES A. WILLIAMSON, A.R.I.B.A., Public Works Office, City Chambers, from whom the necessary documents may be had on personal application on and after Monday, the 12th curt.

Schemes and Tenders must be lodged with the Subscriber by Four p.m. on Monday, the 9th proximo, in official envelopes to be supplied, sealed and marked outside "Tender for Laundry Engineering, Causewayside Washhouse."

The Town Council shall not be bound to accept the lowest or any Tender.

A. GRIBBON,
Town Clerk.
City Chambers,
Edinburgh, 9th January, 1920. C 881

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:—

No.		Fee for Specification.
1.	Steel Work for Bridges	£1
2.	Zinc Sheets, &c.	10/-
3.	Spring Steel	5/-
4.	Ropes, Twines, &c....	10/-
5.	Carriage Door Handles, Hinges, &c.	10/-
6.	Canvases, &c.	£1
7.	Linoleum	7/6
8.	Drawn Brass Angles, &c.	5/-

Specifications and Forms of Tender may be obtained at this Office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned marked "Tender for Steel Work for Bridges," or as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 27th January, 1920.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.
Company's Offices,
48, Copthall Avenue, E.C. 2.
London, 14th January, 1920. C 867

APPOINTMENTS OPEN.

A Large Firm of Engineers

in the Midlands have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4360, Offices of ENGINEERING.

TECHNICAL INSTITUTE, WALTHAMSTOW.

Principal—JAMES G. B. EDWARDS, A.M.I.M.E.

The Governors invite

Applications for the Post of

TEACHER of ENGINEERING SUBJECTS. Commencing salary £300 per annum. Candidates should have an Engineering Degree or its equivalent together with practical workshop experience.

Application forms, which should be returned by January 24th, may be obtained from R. DEMPSEY, Clerk to the Governors, 1, Selborne Road, Walthamstow, E. 17. C 909

HUDDERSFIELD TECHNICAL COLLEGE.

Applications are Invited for

the POSITION of LECTURER in MECHANICAL ENGINEERING. Initial salary £400.—Further particulars may be obtained on application to the SECRETARY, Technical College, Huddersfield. C 869

UNIVERSITY OF BRISTOL.

FACULTY OF ENGINEERING.

Instructor in Engineering

DRAWING. £300–£25–£350.—For particulars and form of application send at once stamped addressed foolscap envelope to the REGISTRAR OF THE MERCHANT VENTURERS' TECHNICAL COLLEGE, Bristol. C 803

DUDLEY EDUCATION COMMITTEE.

TECHNICAL SCHOOLS.

Principal—J. H. Grindley, D.Sc., M.I.Mech.E.

The Committee invite

Applications for the Post of

CHIEF LECTURER in Mechanical Engineering at the Technical Schools. Candidates must possess a degree in Engineering or its equivalent.

Commencing salary £400.

Further particulars can be obtained from the PRINCIPAL. Applications must be made on forms supplied by the undersigned, and returned to him not later than Thursday, January 29th.

J. M. WYNNE,
Director of Education.
Education Offices,
Dudley. C 899

BOOTLE EDUCATION COMMITTEE.

TECHNICAL SCHOOLS.

Required, for Duty on 1st April,

1920, a FULL-TIME TEACHER for the Technical and Junior Technical Schools.

Candidates are required to have had works and drawing office experience in an engineering works, to be graduates holding a pure science or engineering degree, and to have had teaching experience. The duties will cover eight day and two evening sessions. Salary £350 per annum pending adoption of new scale.

Applications should reach PRINCIPAL, Municipal Technical School, Bootle, Lancs., by 28th February, 1920. Further information may be obtained on application to the Principal.

9th January, 1920. C 905

THE POLYTECHNIC SCHOOL OF ENGINEERING.

309, Regent Street, W. 1.

Required Immediately for

MECHANICAL ENGINEERING STAFF, WHOLE TIME ASSISTANT, Honours Degree or equivalent. (Day and Evening work, Ten Sessions). Commencing salary £325–£315, rising to £440 in accordance with the L.C.C. scale for Technical Teachers.

Application forms may be obtained from THE DIRECTOR OF EDUCATION.

(Enclose stamped addressed foolscap envelope.) C 822

LONDON COUNTY COUNCIL.

Applications are Invited for

the POSITION of PRINCIPAL of the new training centre for disabled sailors and soldiers in the electrical and engineering trades at Hackney Marshes. Salary at the rate of £600 a year. Preference will be given to those who have served, or attempted to serve, with the forces of the Crown. Apply to the DIVISIONAL DIRECTOR of INDUSTRIAL TRAINING, 1, Temple Avenue, E.C. 4. (Stamped addressed foolscap envelope necessary.) A form giving particulars will then be sent which must be returned by 11 a.m. on 24th January, 1920.

JAMES BIRD,
Clerk of the London County Council. C 931

Automobile Research Asso-

CIATION: TECHNICAL SECRETARYSHIP. Salary not less than £1000 per annum, terminable at three months' notice. Office in London. Applications must be made on the forms, obtainable on written application, BOX No. C 839, Offices of ENGINEERING.

CITY OF BIRMINGHAM.

WATER DEPARTMENT.

APPOINTMENT OF SECRETARY.

The Water Committee invite

Applications for the Secretary-

SHIP of the Corporation Water Department. The person appointed will, subject to the control of the Water Committee, have charge of the commercial and financial side of the Department, and must have a sound commercial training with responsible experience in some large mercantile, manufacturing or water supply undertaking. He will be required to give his whole time to the duties of his office, and must not engage in private work of any kind. The appointment will be terminable by either party at any time on three months' notice.

The successful candidate will be required to contribute to the Corporation Superannuation Scheme.

Applications, stating age, salary required, present occupation and previous experience, should be sent, accompanied by copies of not more than three testimonials, addressed to—

THE CHAIRMAN,
Water Committee,
Council House,
Birmingham.

Each application must be endorsed on the envelope "Appointment of Secretary," and must reach this office not later than noon, 30th January, 1920.

F. H. C. WILTSHIRE,
Town Clerk.
Council House,
Birmingham.
23rd December, 1919. C 845

THE PRINCIPLES AND PRACTICE OF SWIVELLING BALL BEARINGS.

By W. E. BAKER, M.C., B.Eng.

(*Concluded from page* 39.)

2. THRUST BEARINGS.

(A) *Single Thrust.*

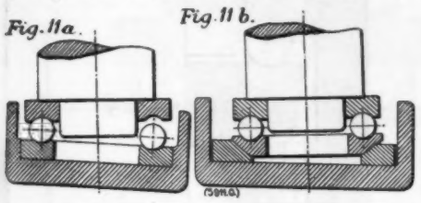
THE question of distributing the load over all the balls in a thrust bearing is of importance, because the design assumes that the balls take equal proportions of the load.

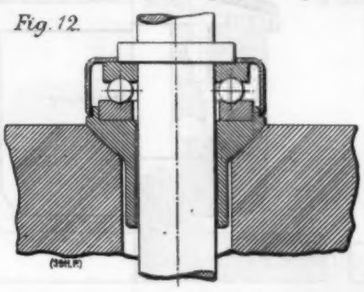
Fig. 11*a* illustrates how the whole of the load is carried by a few only of the balls if the housing is not at right angles to the axis of rotation. Fig. 11*b* illustrates how this error is corrected by the use of a spherical seating. Similarly to the case of the journal bearing, an angular error on the revolving part cannot be corrected by the use of a spherical seating on the stationary part, as swivelling would be necessary at each revolution, and it is impossible to meet this requirement in practice. Contrary to the case of a journal bearing an angular error on the rotating part can be corrected by the use of a swivel seating on that part, as there will then be no tendency to creep. This condition is seldom met in practice, but Fig. 17*d* is an example.

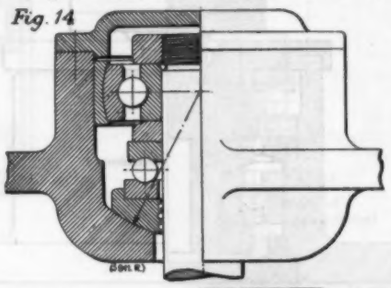
In some cases the swivelling seating of a thrust bearing has to be arranged to correct the angular error on the stationary part progressively during running; this condition will be met where the shaft is revolving on plain journal bearings, which will wear and cause the shaft to take up a continuously varying position. Fig. 12 shows how by journalling the swivelling seating to the shaft, the swivelling movement is enabled to take place progressively without stressing the balls. No journal load must be taken on this plain bearing as the consequent wear would interfere with the concentricity of the stationary thrust race.

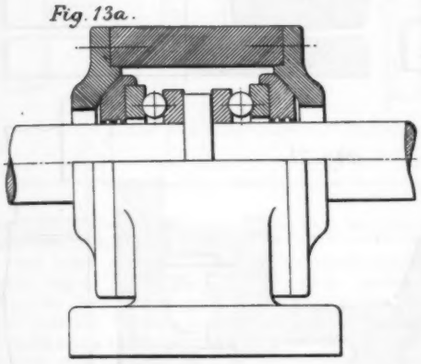
(B) *Double Thrust.*

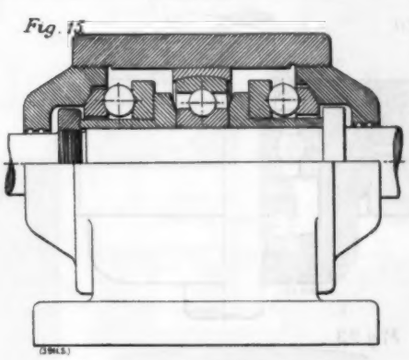
A double thrust bearing can be treated in the same manner and Fig. 13*a* shows one method of accomplishing this. It should be pointed out that extreme care will be necessary to obtain adjustment of the mounting to ensure that there is no end play allowed on the shaft, and also that the balls have not been nipped by tightening the end covers up too much. A similar type of mounting could be used with a double thrust bearing having three races only (the middle race having a smaller bore than the two outer races) by means of splitting the shaft as indicated in Fig. 13*b*.

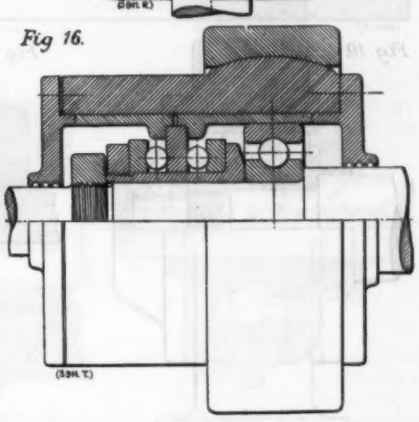


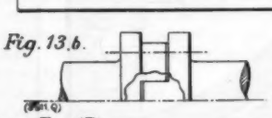


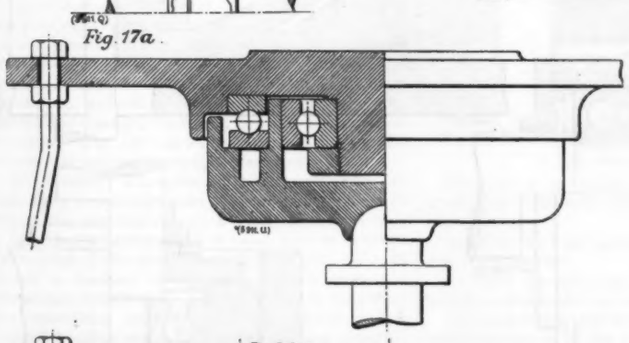


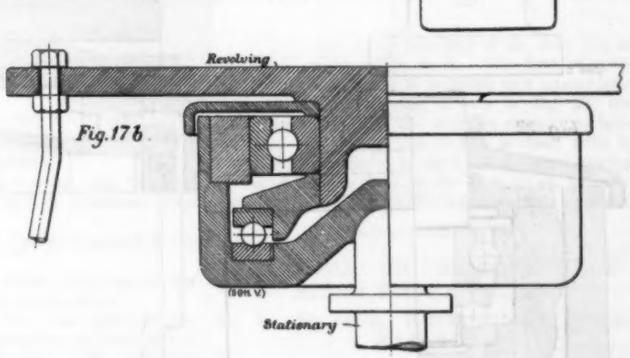


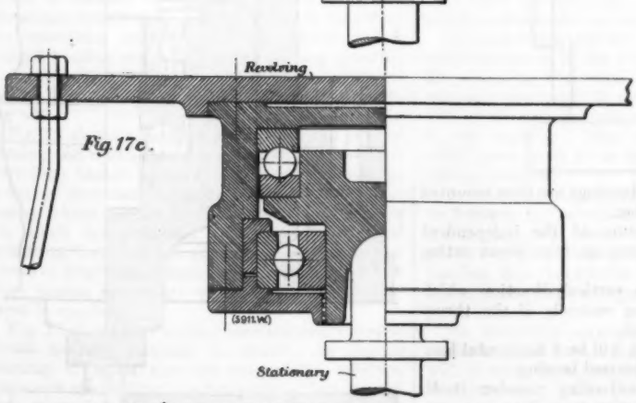


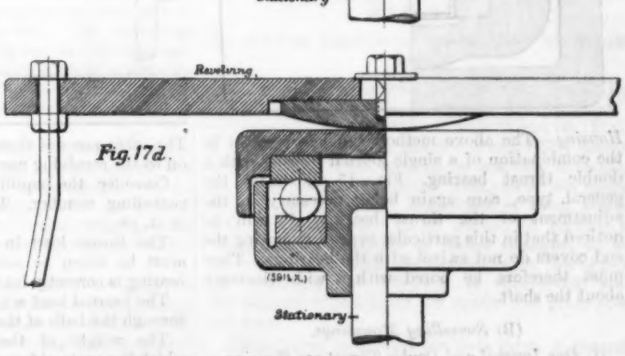












3. COMBINED MOUNTINGS.

(A) *Using Swivelling Bearings.*

(i) *One Journal and Single Thrust per Housing.*—The combination of ball journal and ball thrust bearings to allow of swivelling movement is easily accomplished. In the case where only one journal bearing has to be accommodated in each housing, it can be done by the use of an annular swivelling bearing and the use of a swivelling seating for the

thrust bearing struck from the same centre. Fig. 14 illustrates this type of mounting.

(ii) *One Journal and Double Thrust Bearing per Housing.*—The above method can be extended to the combination of a single journal bearing with a double thrust bearing. Fig. 15 illustrates the general type, care again being necessary in the adjustment of the thrust bearing. It will be noticed that in this particular type of mounting the end covers do not swivel with the bearings. They must therefore be bored with a wide clearance about the shaft.

(B) *Swivelling Mountings.*

(i) *One Journal and Double Thrust per Housing.*—Although a swivelling mounting calling for one journal bearing only in each housing can usually be arranged as indicated in Fig. 15, it is sometimes advantageous to use a non-swivelling annular bearing mounted in a swivelling housing. Fig. 16 shows a mounting of this type.

(ii) *Principles of Swivelling Mountings.*—The principles underlying these swivelling mountings require investigation. The first example given is that of a revolving framework supported at the top on a central pillar. Fig. 17*a* indicates a design which might be put forward. The top of the post is rounded to carry an independent swivelling member which supports the lower race of a thrust bearing and holds the outer race of a journal bearing. The other races of these bearings are then mounted on to the revolving member.

Consider the equilibrium of the independent swivelling member. There are four forces acting on it, viz. :—

The thrust load in a vertical direction which must be taken as acting centrally if the thrust bearing is correctly loaded.

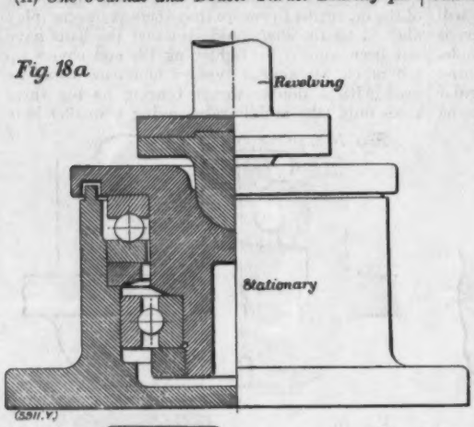
The journal load which will be a horizontal load through the balls of the journal bearing.

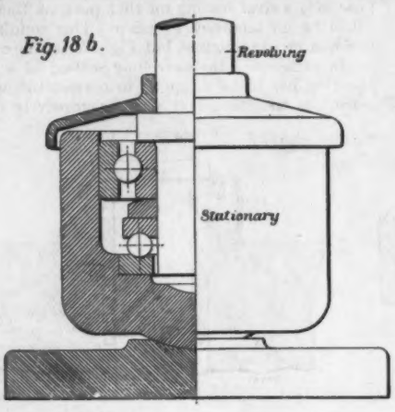
The weight of the swivelling member itself, which is a vertical force acting centrally.

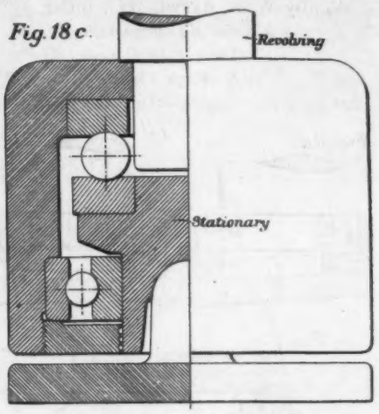
The reaction of the spherical seat.

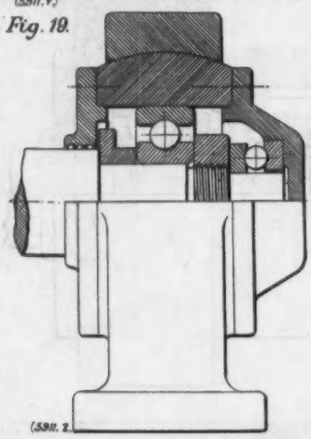
This latter may be analysed into a vertical force acting centrally, and a horizontal force acting at the centre of horizontal pressure. It will be seen that the vertical forces will be equal and opposite, but this is not the case with the horizontal forces as the journal bearing is not opposite the spherical seating. The swivelling member therefore tilts, and this causes the balls on one side of the thrust bearing to be overloaded.

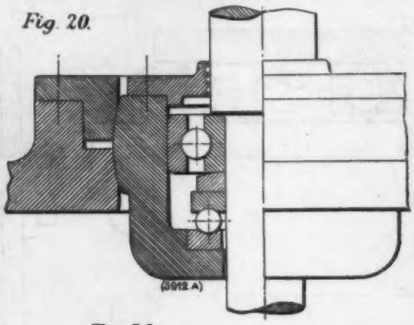
Fig. 17*b* shows an attempt to make the working conditions of the thrust bearing better, by bringing the thrust bearing below the spherical seating. The fundamental error stated in the preceding paragraph is still uncorrected, and the thrust bearing will still be overloaded at one side whenever journal load occurs. Fig. 17*c* shows how this error in mounting is eliminated, by bringing the journal bearing opposite the spherical seating.

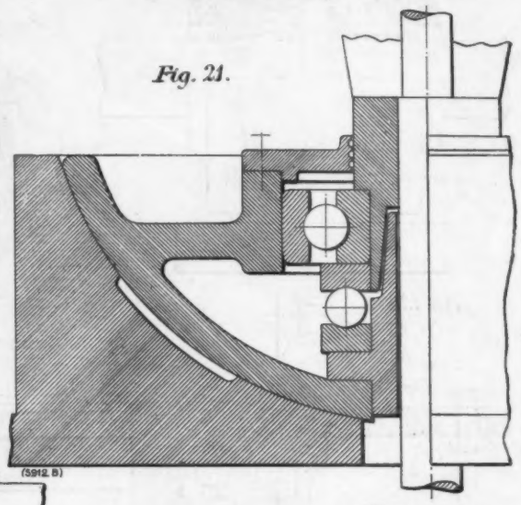


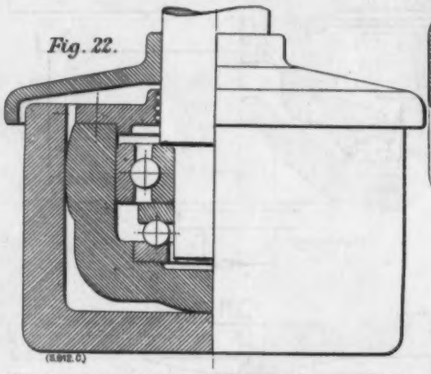


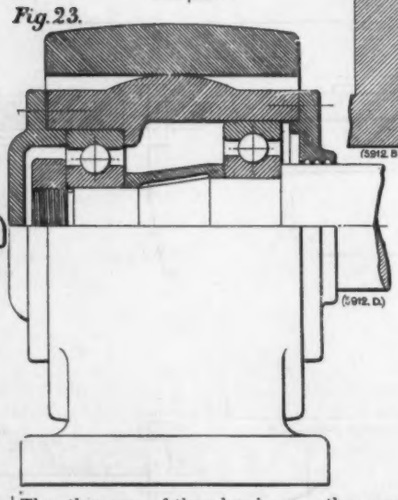


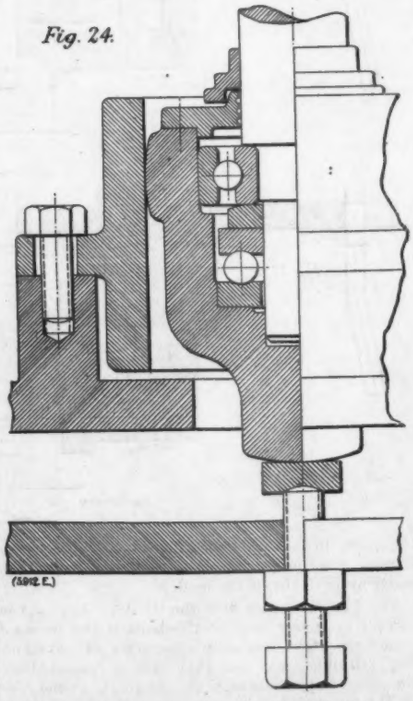












If the mounting can be arranged to be free from journal load, as, say, by journalling the revolving member about the post lower down, then the journal bearing in the mounting can be eliminated altogether. Fig. 17*d* shows a thrust bearing mounted up on the same shaft where arrangements have been made to eliminate journal load.

The same question may also be investigated with regard to a design of footstep bearing Fig. 18*a* shows a revolving shaft with a spherical end mounted into a footstep containing a journal bearing and a thrust bearing. The mounting is not correct, as if the shaft is called upon to swivel, the bearings no longer revolve about the axis of rotation of the shaft. This will cause sliding friction on the spherical surface.

Fig. 18*b* shows this error corrected by mounting the bearings on the end of the shaft, but the design shown introduces the error previously discussed of not having the journal bearing opposite the spherical surface. As before, tilting of the independent swivelling member will occur with consequent unequal loading of the balls in the thrust bearings. Fig. 18*c* shows how this error can be eliminated and the mounting corrected.

(iii) *Further Examples.*—Further examples of swivelling mountings may now be given. Fig. 19 shows the combination of a ball journal bearing, a ball thrust bearing and a plain disc to prevent movement of the shaft from right to left. Fig. 20 shows a method of mounting which does not necessitate splitting the outside casing to introduce the swivelling member. Fig. 21 shows a ball journal bearing and a ball thrust bearing mounted in a swivelling basket at the top of a vertical shaft. The mounting includes a device for retaining oil.

Fig. 22 shows a footstep in which a ball journal bearing and a ball thrust bearing are mounted in a swivelling basket. The disadvantage of this type is that if the basket is made a good fit in the outer casing, whilst upright, it will not be a good fit after the shaft has swivelled. The general type of mounting, however, has advantages inasmuch as it allows of longitudinal movements. Figs. 23 and 24 show similar mountings where longitudinal movement is required.

Fig. 25 shows two journal bearings and a double thrust bearing mounted to swivel. As journal bearings of equal size are shown, the spherical surface is struck from a point midway between the two journal bearings. This may be compared with the design in Fig. 23, where unequal sizes of journal bearings call for the spherical surface being struck from a point not midway between the two bearings.

4. Application to Roller Bearings.

The preceding remarks apply equally to short roller bearings shown in Figs. 26*a* and 26*b*. It will be seen that the outer race of the non-swivelling type of roller bearing is bored cylindrically, without a groove. Where this bearing is used, both races will always have to be held endways to prevent the bearing coming adrift. Advantage of this geometrical property has already been taken in Fig. 10*b*, on page 38 *ante*, discussed in paragraph 1 (*d*). The swivelling roller journal bearing is formed with grooves in both inner and outer races, and can therefore be substituted for any of the swivelling ball journal bearings without alteration to the design

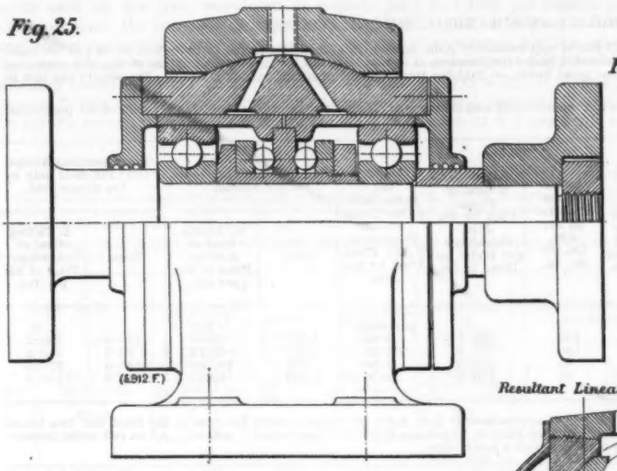
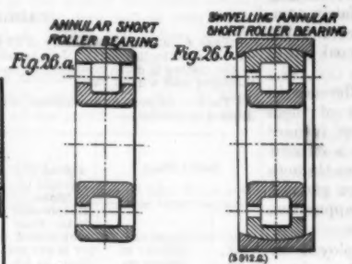


Fig. 25.



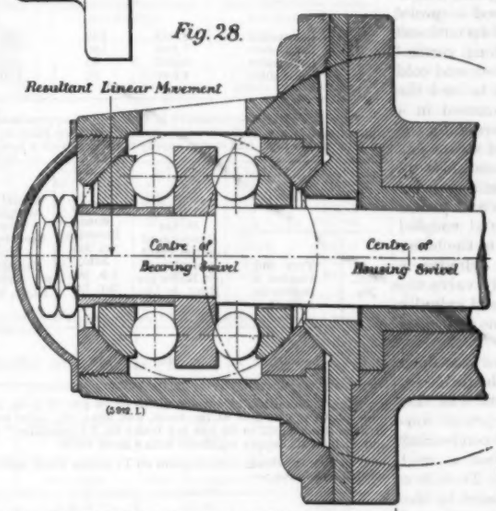


Fig. 28.

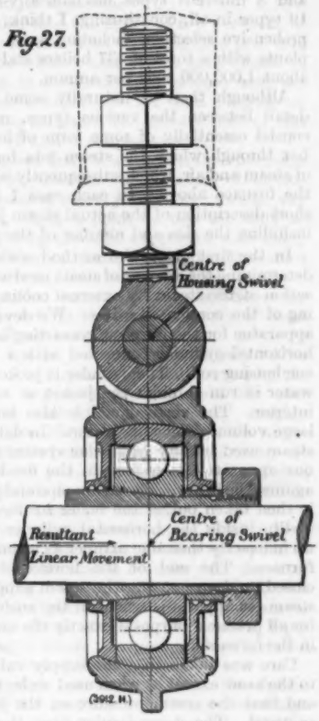


Fig. 27.

5. Deductions.

Even in a swivelling mounting, the bearings must run true with the axis of rotation. This necessitates—

(*a*) That the bearings are rigidly connected to the revolving member.

(*b*) That the revolving member runs true at the point on which the bearings are mounted.

The swivelling motion must take place on the stationary races of the bearings or on some part of the mounting connected thereto. The swivelling will take place only in fitting up, *i.e.*, the bearings will set themselves in the position most conducive to free running. They will not swivel (nor be called upon to do so) at each revolution of the revolving member.

In cases where an independent member is arranged to provide the swivelling, the equilibrium of this member must be considered in the design. In the case of a mounting embodying only one journal bearing, this necessitates the journal bearing being opposite the point of support in the direction of the journal load.

No swivelling arrangement based on spherical surfaces struck from a single centre in each housing will correct displacement errors (as distinct from angular errors) where the revolving part is carried by more than two independent housings, which are not in line. This does not apply in practice in cases similar to line shafting where the diameter of the revolving shaft is small compared to the distance between bearings. The end covers should be arranged to swivel with the bearings in order to obtain a dust-proof mounting.

To obtain the maximum freedom in swivelling the radius of the swivel surfaces must be kept as small as is compatible with other conditions; portions of this swivel surface on the rigid member should be cut away where possible, and efficient arrangements made for lubrication.

No treatment of this subject would be complete without reference to arrangements in which swivelling is allowed to take place about two separate centres. By this means, displacements of the shaft can be accommodated in two directions, viz., in the direction of the shaft and at right angles to it. The first of these conditions is satisfied in a patent line-shaft bearing, shown in Fig. 27, the object being to allow the shaft to expand without stressing the balls. The second is dealt with in another patent device to allow a ball thrust bearing to accommodate itself to the wear in an adjacent plain bearing. Fig. 28 illustrates the arrangement.

EXACT DATA ON THE RUNNING OF STEAM BOILER PLANTS.

By D. Brownlie, B.Sc.Hons.(Lond.), F.C.S., A.I.Mech.E.

No. 3.—The Amount of Steam Used by Steam Jets.

In the original article entitled "Coal Saving by the Scientific Control of Steam Boiler Plant," published in Engineering of July 12 and 19, 1918), I showed that out of the 250 steam boiler plants typical of the whole country, no less than 93 plants, or 37 per cent., were fitted with steam jets under or over the fire-bars. The object of using steam jets in this manner is, of course, to provide a cheap and simple form of forced draught, so as to force air through the furnace with the object of increasing the efficiency of combustion and the amount of fuel burnt per square foot grate area per hour.

There seem to be very few data given in general engineering literature as to the amount of steam used by these jets. The makers of the various types of furnaces and mechanical stokers using steam jets as a rule confess to a modest 1 per cent. to 3 per cent. of the steam production, and at any rate in many years' experience I have only heard of one maker who has admitted a figure of over 3½ per cent. In the original article above referred to I stated that the average consumption of steam by the jets for the 93 plants was 5·6 per cent. of the total steam produced, but that the figure varied on different plants from 1 per cent. to 20 per cent. In the present article I propose to deal with this

question in more detail, and to consider the figures derived from 130 plants.

I do not know exactly the number of different makers of such apparatus on the market, but we have investigated 11 different types, hand-fired, and 8 different types mechanically-fired, making 19 types in all, constituting, I think, a fairly comprehensive selection, including as it does the 130 plants with a total of 437 boilers and a coal bill of about 1,000,000 tons per annum.

Although there is naturally some difference in detail between the various types, most of them consist essentially of some form of hollow furnace bar through which the steam jets force a current of steam and air, which subsequently passes through the furnace above. In each case I have given a short description of the actual steam-jet apparatus, including the size and number of the jets.

In the first place, the method we employed for determining the amount of steam used was by condensation of the steam by external cooling, and weighing of the condensed water. We devised a special apparatus for the purpose, consisting of an enclosed horizontal cylinder connected with a long vertical condensing coil. The cylinder is jacketed, and cold water is run through the jacket so as to cool the interior. The vertical coil is also immersed in a large volume of cooling water. In determining the steam used by any particular system of steam jets our apparatus is erected in the fire-hole close up against the boiler. The steam pipe and jet apparatus is then taken out of the boiler furnace and placed bodily inside the horizontal cylinder and coupled up in exactly the same manner as when in the boiler furnace. The end of the horizontal cylinder is closed, and on opening the steam supply valve the steam-jet apparatus works in the enclosed cylinder for all practical purposes exactly the same as it does in the furnaces.

Care was taken that the supply valve was open to the same extent as when used under the furnaces, and that the steam pressure on the jets was also as usual. The steam issuing from the jets is condensed in the horizontal cylinder and the condensing coil, and runs out of the end of the coil as cold condensed water, and is weighed direct. There is a very minute pressure in the cylinder caused by the small resistance to the passage of the condensed water through the coil, and this will tend therefore to make the figure for the steam used by the jets very slightly lower than would be the case in the open air in the furnaces, and this slight error, if appreciable, is therefore on the right side. In this way a series of observations were carried out, say, three or four successive determinations of one half-hour each, and if the figures for the several determinations were similar this was sufficient. If there was much difference a further series of determinations was carried out to get good average figures. A fair amount of judgment is, of course, necessary in these determinations. In the first place there is the question of the amount of opening of the steam supply valve to the jets. On a ½-in. or ¾-in. pipe, for example, say, three-quarter turn is generally the same as full open as regards the amount of steam passed, but in 90 per cent. of cases the firemen simply open the valve full open, that is two or three turns, and leave it all day continuously in this position. In such a case the method of determination is simple, the valve being full open. In some cases, however, the firemen are more careful and work with, say, quarter turn open on an 8-hour shift for, say, 6 hours, and full open for, say, 2 hours, when cleaning out or when the load is particularly heavy.

In such a case the practice of the firemen was carefully observed, and separate determinations were carried out accordingly with the valve quarter turn open and full open. The two results were then averaged up in the proportion of 6 hours to 2 hours, and in this way a good average determination was secured.

Secondly, there is the question of variation in the steam pressure. This presents no difficulty in the case of most boiler plants where the steam pressure is kept up to within a reasonable margin of, say, 20 lb. In those cases where the steam pressure cannot be maintained within reasonable limits it is necessary to carry out the determination at various pressures and average the results approximately in the proportion of the pressures being obtained in practice.

There is also the question of the wearing action of the steam on the size of the holes or nozzles through which the steam is blowing. The holes gradually tend to wear larger, depending on the time the apparatus has been in operation, and therefore different results may be obtained with the same apparatus depending on this condition. Our determinations were carried out exactly as we found the plants working, and because of the large number of plants we have tested the conditions in this respect must, as a whole, be regarded as affording an excellent average.

I can only say that great care was taken with the determinations, and in actual practice the difficulties are not nearly so great as they may appear; in fact, I feel convinced that the results are accurate at any rate to ½ per cent. That is to say, a figure determined by us of, say, 5 per cent., will not be outside the limits of 4½ per cent. to 5½ per cent. from week to week on the plant.

In Tables I and II, on Plate III, published with this issue, and Table III, on the present page and page 73, I give the actual results obtained

TABLE III.—MECHANICAL FIRING (COKING TYPE).

Type A.—Consists essentially of 37 jets of approximately $\frac{1}{16}$-in. holes in a special casting per furnace (that is, 74 jets per boiler on "Lancashire" boilers). Jets are situated under the furnaces at the back on full boiler pressure, but the steam pipe connected to the casting is much restricted at one point inside, so that the total amount of steam passing is small. The supply can also be regulated with a hand valve.

The average steam consumption on four plants fitted with this type of steam-jet apparatus is about 2·3 per cent. of the production, divided as follows:—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30s. per ton.	Tons.	£, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	2 Lancashire ..	8,059	189	186·5	1·30	5,500	8,250	126·5	190·2
2	1 Lancashire ..	7,906	150	173·9	2·25	4,250	6,375	93·5	140·2
3	5 Lancashire ..	6,037	90	150·9	2·50	7,400	11,100	185·0	277·5
4	4 Lancashire ..	4,081	52	110·2	2·70	3,900	5,850	105·3	157·9

Type B.—Consists essentially of four jets of approximately ½-in. holes per furnace under the fires at the front and two jets of approximately ¼-in. holes over the fires per furnace (that is, 12 jets per boiler on "Lancashire" boilers). All on full boiler pressure on ¾-in. steam pipe, and steam supply regulated with a hand valve.

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30s. per Ton.	Tons.	£, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	3 Lancashire ..	5,144	113	711·1	13·8	5,750	8,625	793·5	1,190·2

Type C.—Consists essentially of 15 or 16 jets of $\frac{3}{16}$-in. holes underneath the furnace at the back, 15 or 16 jets of $\frac{3}{16}$-in. holes underneath the furnace at the front, and often one large jet, generally a ½-in. steam pipe, flattened at the end over the top of the furnace (that is, 62 to 66 jets per boiler on "Lancashire" boilers). All jets generally on ¾-in. steam pipe on full boiler pressure and with steam supply regulated with a hand valve.

The average steam consumption on 13 plants fitted with this type of steam-jet apparatus is about 8 per cent. of the production, divided as follows:—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30s. per ton.	Tons.	£, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	3 Lancashire ..	6,997	144	nil	0·00	4,000	6,000	nil	nil
2	1 Lancashire ..	4,659	107	69·8	1·50	1,750	2,625	26·2	39·4
3	16 Lancashire ..	9,528	105	330·6	3·47	79,000	118,500	4,321·3	6,481·9
4	5 Lancashire ..	7,312	102	420·4	5·75	19,500	29,250	1,121·2	1,681·8
5	16 Lancashire ..	4,347	102	324·8	7·47	26,250	39,375	1,960·8	2,941·2
6	2 Lancashire ..	6,431	90	488·7	7·60	7,700	11,550	585·2	877·8
7	4 Lancashire ..	2,990	75	239·2	8·00	8,500	12,750	680·0	1,020·0
8	5 Lancashire ..	5,933	106	548·8	9·25	15,250	22,875	1,410·6	2,115·9
9	1 Lancashire ..	5,393	54	517·7	9·60	1,550	2,325	148·8	223·2
10	3 Lancashire ..	5,408	84	523·0	9·00	18,500	27,750	1,776·0	2,664·0
11	2 Lancashire ..	6,583	147	688·0	10·40	5,500	8,250	572·0	858·0
12	2 Lancashire ..	5,915	160	1,041·0	17·60	6,950	10,425	1,223·2	1,839·8
13	6 Lancashire ..	6,861	81	1,468·2	21·40	17,500	26,250	3,745·0	5,617·5

Type D.—Consists essentially of nine jets of approximately ½-in. holes on ¾-in. steam pipe per furnace (that is, 18 jets per boiler on "Lancashire" boilers) underneath the fires at the back. All jets on full boiler pressure and steam supply regulated with a hand valve:—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30s. per Ton.	Tons.	£, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	3 Lancashire ..	7,737	78	557·2	7·2	4,900	7,350	352·8	529·2

with the 19 types of steam-jet apparatus, showing the number of boilers on each plant, the actual net weight of the steam evaporated by the plant calculated in pounds per boiler per hour, the actual steam pressure on the jets, the exact net weight of steam used by the jets, calculated in pounds per boiler per hour, the corresponding percentage of the total steam production of the plant used by the jets, the annual coal bill of the plant, and the corresponding annual coal bill used by the jets. I also give in Tables IV and V subjoined the averages of the results recorded in the preceding Tables.

TABLE III.—MECHANICAL FIRING (COKING TYPE)—*Continued.*

Type E.—Consists essentially of seven jets of approximately $\frac{1}{16}$-in. to $\frac{1}{8}$-in. holes on $\frac{1}{2}$-in. steam pipe per furnace (that is, 14 jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces on full boiler pressure and the steam supply regulated with a hand valve which is generally full open.

The average steam consumption on nine plants fitted with this type of steam-jet apparatus is about 7·5 per cent. of the production, divided as follows:—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30s. per ton.	Tons.	£, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	2 Lancashire ..	4,463	187	174·9	3·92	3,750	5,625	147·0	220·5
2	10 Lancashire ..	6,927	136	313·1	4·52	33,000	49,500	1,491·0	2,237·4
3	4 Lancashire ..	7,702	98	431·3	5·60	14,500	21,750	812·0	1,218·0
4	4 Lancashire ..	4,211	74	253·5	6·02	4,500	6,750	270·9	406·3
5	13 Lancashire ..	7,401	112	488·4	6·60	38,500	57,750	2,541·0	3,811·5
6	3 Lancashire ..	5,946	114	417·4	7·02	6,500	9,750	457·3	684·5
7	9 Lancashire ..	4,955	80	361·7	7·30	32,000	48,000	2,336·0	3,504·0
8	3 Lancashire ..	7,382	145	590·5	8·00	11,500	17,250	920·0	1,380·0
9	15 Lancashire ..	6,533	157	741·7	11·35	41,000	61,500	4,653·5	6,980·0

The approximate average of the whole 130 plants comprising 437 boilers with an annual coal bill of approximately 1,000,000 tons works out at 6·6 per cent. of the steam production, divided as follows:—

TABLE IV.—GIVING AVERAGE RESULTS FOR HAND FIRING.

Averages 6·6 per cent. of the production.

Type of Apparatus.	No. of Plants.	No. of Boilers.	Percentage of Production.	Total Coal Bill.	Total Coal Bill Used by Jets.
			per cent.	tons per annum.	tons per annum.
Type A	6	17	7·6	20,200	1,535·2
Type B	4	7	4·5	15,400	693·0
Type C	3	6	7·3	9,234	674·0
Type D	18	60	6·3	137,005	8,631·5
Type E	7	22	8·1	55,450	4,491·4
Type F	2	3	3·2	5,850	187·2
Type G	2	4	5·0	6,600	330·0
Type H	2	6	7·7	14,400	1,108·8
Type I	3	6	4·4	8,525	375·1
Type J	1	2	15·25	4,000	610·0
Type K	6	16	5·9	35,346	2,079·5
	54	149		312,010	20,715·7

TABLE V.—GIVING AVERAGE RESULTS FOR MECHANICAL FIRING.

Averages 6·7 per cent of the production.

Type of Apparatus.	No. of Plants.	No. of Boilers.	Percentage of Production.	Total Coal Bill.	Total Coal Bill Used by Jets.
			per cent.	tons per annum.	tons per annum.
Type A.—Sprinkling	25	73	5·00	140,345	7,017·2
Type B.—Sprinkling	16	45	5·25	95,550	5,016·4
Type C.—Sprinkling	7	23	5·00	30,070	1,503·5
Type A.—Coking	4	12	2·30	21,050	484·1
Type B.—Coking	1	3	13·80	5,750	793·5
Type C.—Coking	13	66	8·00	221,950	17,756·0
Type D.—Coking	1	3	7·20	4,900	352·8
Type E.—Coking	9	63	7·50	185,250	13,893·7
	76	288		704,865	46,817·2

It will be obvious from the results recorded in these tables that the figures given by a number of makers of steam-jet apparatus are quite erroneous, and the amount of steam used is seriously in excess of what is generally supposed.

One of the most striking facts is the enormous difference between the amounts of steam used by these steam jets; thus the lowest figure obtained was 0·50 per cent. of the production and the highest 21·4 per cent. The differences on different plants using the same make of apparatus are also very remarkable.

The great cost of running steam jets in average cases is not realised. Thus, taking an average-sized boiler plant of six "Lancashire" boilers burning, say, 12,000 tons of coal per annum, equivalent to 18,000*l.* per annum, with coal at an average price of 30*s.* per ton. The cost of an ordinary steam-jet apparatus hand-fired would be about, say, 100*l.* per boiler, equal to 600*l.* for the plant.

Taking the average figure of 6·6 per cent. of the steam production used by the jets, this corresponds to 1,188*l.* per annum as the cost of the steam used, equal to buying an entirely new set of steam-jet apparatus for the whole of the six boilers about every six months.

For a similar plant a mechanical stoker equipment would cost about double, say, 1,200*l.*, and in this case at 6·5 per cent. of the steam production, this would be equivalent to replacing the whole of the stokers every twelve months. In addition, also, in the latter case the cost of upkeep of the stokers has to be taken into account, whilst in the case of hand-fired steam-jet apparatus the fire-bars last a very long time because of the "cooling" action of the steam.

This is, of course, merely speaking of averages, but some of the actual instances are astounding, as will be seen from the tables. Of the whole 130 plants, 29 plants have coal bills of over 1,000*l.* per annum incurred by the use of steam jets alone, whilst the number of plants with coal bills of 500*l.* or over is 47.

I do not know, of course, what proportion of boiler plants in the country are fitted with steam-jet apparatus. On the 250 plants the number was 93, that is 37 per cent. Assuming that this figure is roughly correct, on the national annual coal bill of, say, 75,000,000 tons to 100,000,000 tons consumed for steam raising, this would correspond to 27,750,000 tons to 37,000,000 tons of coal burnt per annum by means of steam-jet apparatus.

Assuming also that the figure of 6·6 per cent. of the steam production used by these jets is a true average for the whole country, this corresponds to 1,831,500 tons to 2,442,000 tons of coal used per annum in the country for the sole purpose of supplying steam to jets. The greater part of this huge amount of coal is simply wasted.

In the first place there is a considerable difference of opinion as to whether the principle of forced-draught by means of steam jets is correct under any circumstances. Such a point as this can only be determined by long practical experience with many different qualities of fuel and under the most varying conditions. Our own experience has been that whilst under certain given conditions the principle is correct, in the great majority of cases the principle is not correct.

Each plant has to be considered entirely on its merits, and it is not realised generally, even by the most scientific engineers, how different the conditions are on different plants. Very roughly probably the conditions obtaining on only about 10 per cent. of the boiler plants of the country are suitable for steam jets, that is the amount of coal burnt by steam jets should only be, say, 7·5 million tons to 10,000,000 tons per annum.

Taking those plants, however, on which it is correct practice to use steam-jets, the next point is the amount of steam that is necessary for the most scientific working. In our opinion, as the result of many years' experience, a steam-jet apparatus in general uses from about 1½ per cent. to 4 per cent. of the total steam production when installed and worked on correct lines.

The reason why in actual practice the figures average about 6·6 per cent., and may be as high as 20 per cent., is due to two causes. Firstly, the design of some of the apparatus on the market is crude and unscientific, and even with the most careful attention it would not be possible to get good results with only 1½ per cent. to 4 per cent. Secondly, and this is by far the most important cause, it is due to unscientific methods in working the plant, and not to defect in the design of the steam-jet apparatus itself.

If a given boiler plant, at present showing extravagant results, was taken in hand and scientific methods of control adopted, figures like 7½ per cent. to 15 per cent. of the steam production would be very soon cut down to 3 per cent. or 4 per cent. with most types of steam-jet apparatus.

This question of steam jets affords another striking example of the utter lack of up-to-date methods in running many boiler plants. Steam-jet apparatus is bought and installed in the most reckless manner without the slightest consideration for the conditions of the plant. In most cases the conditions are not suitable for such apparatus at all, and it is then impossible to get good results even with the best type of apparatus. Some of the types of apparatus on sale are inherently defective in design, and would not give good results even under the most favourable conditions. Finally, when the apparatus is installed, in most cases it is not worked correctly, and the good class of such apparatus does not get a fair chance to show its efficiency.

It is not to be wondered at therefore that the average figure for the steam consumption is 6·6 per cent., although it certainly does seem incredible that dozens of firms of high repute should be squandering 10 per cent. to 15 per cent., and even 20 per cent. of their coal bill in this manner.

It is obviously somewhat difficult to give figures for the national saving to be obtained in this direction. On the assumption that 6·6 per cent. is an average figure, as already seen, this corresponds at present to 1,831,500 tons to 2,442,000 tons per annum. Probably about two-thirds of the steam jets now at work in the country are quite unsuitable for the conditions under which they are used and should be replaced by mechanical draught. This latter takes about 2·5 per cent. of the steam consumption, so that the saving in

these cases would be, say, 750,000 tons to 975,000 tons per annum.

Of the remaining one-third retaining the use of steam jets the figure of 6·6 per cent. should be cut down to an average of, say, 3·5 per cent. This would correspond to a saving of, say, 275,000 tons to 370,000 tons per annum, making a total saving for the whole country in round numbers of 1,025,000 tons to 1,345,000 tons per annum, equal in value to, say, 1,500,000*l.* to 2,000,000*l.*, taking coal at an average price of 30*s.* per ton in the fire-hole.

Such an enormous saving as this in steam generation in connection with one item only in the boiler-house, namely, steam jets, will give an idea of the large field for economy that is opened up by the adoption of complete scientific methods in the boiler-house. Also in considering national coal economy by the adoption of super power stations, it emphasises the huge economy that can be effected by bringing up to date the already existing boiler and power plants of the country at a mere fraction of the cost involved under the super power station scheme.

AIR-PUMP CAPACITIES AND INCONDENSIBLE-GAS VOLUMES IN INDUSTRIAL VACUUM-EVAPORATOR PLANT.

By EDWARD CORNER.

THE rather unfortunate general use of empirical formulae for the determination of air-pump capacities in evaporator work, has led the writer to attempt to lay down in a clear and concise manner, the theoretical principles entailed, with practical data, and a set of curves, which will enable designers to choose the correct value for any particular case.

Empirical formulae are undoubtedly most useful in average cases, and under satisfactory conditions designs obtained by their use, are good enough for practical purposes, but many cases have occurred in which a fuller knowledge of the root principles would have been of extreme value to the designer, and would undoubtedly have enabled him to produce a more efficient, and satisfactory apparatus. It is often remarked by draughtsmen and engineers, who have been connected with more than one firm, how great the variation is between the empirical figure taken in one shop, and that taken in another, and the writer is personally acquainted with three different values for the capacity of dry-air pumps, values which differ so greatly, that it is difficult to explain the fact that these firms are all makers of very satisfactory plants.

Now, empirical formulae, especially as regards condensation problems, can only be considered accurate or practically accurate between certain limits, *i.e.*, a single value for, say, air-pump capacity cannot be expected to cover all variations of injection temperature, vacuum, or hot-well temperature, and it is essential that in many cases an accurate factor should be obtained, applicable to the particular conditions prevailing.

The possible vacuum in any condenser is directly due to the absolute pressure in the condenser, this absolute-pressure, being the sum of the partial pressures of water-vapour and air or other incondensible gases present.

According to Dalton's Law, any number of gases enclosed in a vessel, will each exert a pressure upon the walls of the vessel, equal to the pressure such gas would have exerted, had it been present alone, and the total pressure in the vessel is the sum of the partial-pressures of all the gases present. Also, each gas occupies the whole space, or in other words, the molecules of the different gases are intimately mixed.

The temperature prevailing in a condenser is, approximately, that of the outgoing or "tail" water, and it is easily seen that this temperature is the governing factor in fixing the vacuum. It is sometimes thought, that the quantity of air relative to steam, entering the condenser, plays an important part in determining the vacuum, but, as the ratio of air to steam is always very small, the actual effect can safely be neglected, and, in fact, has no influence whatever in the latter part of the condensation, *i.e.*, after the latent heat has been removed. Immediately after condensation of the steam, the ratio of air to vapour, becomes very greatly increased, and the partial pressure of the air becomes a very important factor in determining the vacuum, and, it is this partial pressure of the air, which explains the difference between the vacuum shown on the gauge, and the vacuum which one would expect, from the relative thermometer reading.

The volume of 1 lb. of air enclosed in a space, at any temperature and pressure, is found as follows:—

$$V_1' = \frac{V_1 P_1 (T_2 + 460)}{P_2 (T_1 + 460)}$$

where V_1 = volume of air in cubic ft. per pound, at 60 deg. F., and 14·7 lb. per sq. in. = 13·1 cub. ft
V_2 = volume as above, at P_2 and T_2.
P_1 = 14·7 lb. per square inch.
P_2 = Pressure of air at T_2 and volume required.
T_2 = 60 deg. F.

Substituting the given values in the above formula, we get:—

$$V_2 = \frac{13{\cdot}1 \times 14{\cdot}7 \times (T_2 + 460)}{P_2 \times 520} = \frac{{\cdot}37\,(T_2 + 460)}{P_2}$$

In a mixture of steam and air, at any given volume and temperature, the volume of the air is equal to the volume of the steam, and also equal to the total volume, and its weight is:—

$$W = \frac{p_2 \times V}{{\cdot}37 \times (T_2 + 460)}$$

where W = weight in pounds of the air contained in the mixed volume.
P_2 = pressure of the air, which is equal to the total pressure minus the pressure of the water-vapour or steam at temperature T_2.

The usual allowances or data for ratio of air to steam, which are applicable to power-plant, are very much too low for industrial evaporator-work, as this latter plant exposes a much greater joint surface, and is working with liquors which contain a large quantity of gases in solution, as well as other gases which are evolved during the evaporation process. On the other hand, the water used for injection is very often, at a much higher temperature than that used in European plant, and thus contains slightly less air, this, of course, is only intended to apply to tropical conditions, and chemical evaporators working in Europe would, naturally, have conditions of injection similar to power-plant in the same locality.

The most reliable figures for incondensible-gas volumes relative to steam entering the condenser, are as follows:—

(1) 4 lb. of air per 1,000 lb. of steam or vapour.
(2) ·2 lb. of air per 1,000 lb. of liquor treated.
(3) ·1 lb. of air per 1,000 lb. of injection-water.

These values are originally intended for sugar-juice evaporators, but can be used with confidence for almost all chemical liquors, and for any temperature of injection. The quantity under heading (2) above, varies with the number of vessels in the evaporator, and a table of constants is given for the various groupings, as the curves are all calculated for the most usual triple-effect grouping; a set of multipliers is also appended, to facilitate calculation.

As previously mentioned, the possible vacuum in any condenser is directly due to the temperature of the "tail" water, and in condensers of the jet type, this tail water is the condensed steam together with the injection water. The formulae for obtaining air-pump capacity for any type of jet condenser, are very similar, only differing in respect of the values taken for the temperature at which the air is withdrawn, and, in the case of barometric, or counter-current jet condensers, the pump is not required to deal with any tailwater, and, thus, no factor for this is embodied.

Now, as stated above, the most important factor in determining the possible vacuum, is the temperature of the tail water, and, indirectly, this temperature greatly affects the volume of air which must be withdrawn. Every pound of injection-water brings with it a certain quantity of air, and thus the greater the quantity of injection-water used, the greater the quantity of air which must be removed. Against this must be placed the fact that, the greater the quantity of injection-water used, the lower will be the temperature of the tail water, and, consequently, a higher vacuum will be obtained, together with a lower air temperature and smaller volume per pound. A set of curves plotted for this purpose, shows a marked diminution of air-pump volume, with increase of injection-water ratio, up to a certain limit, after which pump-capacity rises rapidly on, still further increasing this ratio.

To find the ratio $\frac{\text{injection water}}{\text{steam}}$ by weight, the following simple formula is used:—

$$W = \frac{L + (T_1 - T_2)}{T_2 - T_3}$$

where W = weight of injection water per pound of steam, per hour.
L = Latent heat of the steam at temperature due to required vacuum or T_1.
T_1 = Temperature of steam at the required vacuum.
T_2 = Temperature of the "tail water."
T_3 = Temperature of the injection.

It is usual to assume T_2, 10 deg. below T_1, for low-level, parallel-flow jet condensers, and 5 deg. below T_1, for barometric or other counter-current jet condensers. These allowances are considered sufficient in most cases, but, the designer must satisfy himself, in special cases, that the temperature difference given by these values is sufficient for the complete transmission of the heat during the passage of the steam through the condenser, or, in other words, that the condenser is of sufficient length. The curves in Figs. 1 and 2, are plotted for conditions as given above, other conditions will, of course, require special calculations, of which formulae are given below, in their respective places.

Low-level parallel-flow condensers.—The air which is to be removed from this type of condenser is withdrawn along with the tail water, and is, therefore, practically at the same temperature, and its volume may be calculated as follows:—

$$V_2 = \frac{V_1 P_1 T_2 + 460)}{P_2 (T_4 + 460)}$$

where V_2 = volume of the air, in cubic ft. per pound at temperature T_2;
P_1 = 14·7 pounds per square inch pressure.
P_2 = Pressure of the air, or, difference between, total pressure in the condenser and the pressure of water-vapour at temperature T_2.
V_1 = 13·1 cubic ft.
T_2 = temperature of the tail water.
T_4 = 60 deg. F.

This formula, as already shown, becomes on substitution:—

$$V_2 = \frac{{\cdot}37\,(T_2 + 460)}{P_2}$$

The pressures used in condenser-work being all below atmospheric pressure, and as temperature is such an important factor, it is found more convenient to take these pressures, in inches of mercury rather than in pounds per square inch, and the above formulæ then becomes transformed to:—

$$V_2 = \frac{{\cdot}37\,(T_2 + 460) \times 2{\cdot}04}{p_2} = \frac{{\cdot}755\,(T_2 + 460)}{p_2}$$

The formula given above enables one to calculate the volume of 1 lb. of air at any temperature or pressure, but, in order to obtain the pump displacement, it will be necessary to revise the above so as to give the volume of air and tail water per pound of steam, and as pump displacement is usually given as, cubic inches per min. per 1 lb. of steam condensed per hour, a further alteration should be made in its construction.

$$D = \frac{{\cdot}755\,(t + 460) \times (k + m) \times 1728}{P_2 \times 60} n.$$

$$= \frac{21{\cdot}8\,(t + 460) \times (k + m)}{P_2} + n$$

where D = Pump-displacement, in cubic inches per min. per 1 lb. of steam condensed per hour.
t = temperature of tail water in deg. F.
P_2 = Pressure of the air (*see above*).
k = a constant, for type of apparatus. *See* Table 1.
m = W × ·0001 or $\frac{\text{lbs. of injection} \times {\cdot}0001}{\text{lbs. of steam.}}$
n = (W + 1) × ·462 = volume of tail-water.
W = weight of injection in lbs. per 1 lb. of steam condenser per hour.

The curves given in Fig. 1 are plotted from this formula, tail water being taken at 10 deg. below temperature proper to vacuum; injection-water quantities are also given, in the dotted curves. The values obtained from these curves are, of course, minimum-values, and should be increased according to the designer's experience, and for the particular type of pump employed; for those unused to this kind of work, the writer suggests an increase of 10 per cent., as being quite sufficient to meet all contingencies.

Barometric condensers, or low-level counter-current apparatus.—In this type the air is withdrawn at a point, either above or very little below, the injection-water inlet, and is, therefore, removed at, or almost at, the temperature of the injection. The air-pump deals with air only, and, as this air is cooler and, therefore, denser, the pump is necessarily smaller than the wet type, of similar condensing capacity.

The formula giving injection water quantity is similar to that given previously, excepting that the temperature of the tail water is taken 5 deg. below temperature proper to vacuum.

The temperature of the air is taken here as being 2 deg. above that of the injection water, and this has

been added to the absolute temperature value, in the formula:

$$D = \frac{\cdot 755\,(t + 462) \times (k + m) \times 1728}{P_2 \times 60}$$

$$= \frac{21 \cdot 8\,(t + 462) \times (k + m)}{P_2}.$$

where the symbols have the same meaning as in the previous formula, except t, which in this case is the temperature of the injection water.

The curves given in Fig. 2 are plotted from the above formula, and, as before, are, of course, minimum values. It will be noticed that a vacuum of 28 in. or over, requires very large pump capacity, when the injection exceeds 70 deg. F., and as this temperature is generally lower than the usual for tropical countries, it is very rare to find apparatus designed for such high vacua, when intended for such localities.

In actual practice a small portion of the air is carried out in the tail water, but it is safer, as a rule, to neglect this quantity.

Surface condensers.—For this type of condenser, very different conditions exist, the steam is condensed without coming into actual contact with the injection, or circulating water, and the quantity of air to be dealt with is correspondingly reduced.

Most surface condensers are designed for counter flow, as this enables the circulating water to be used to the greatest advantage and also allows the lowest possible temperature of the condensate, being obtained.

There is a great deal in the design of surface-condenser plant, which depends upon special conditions, and as this is beyond the scope of the present article, the writer offers the curves in Fig. 3, as being only a guide, as it is almost impossible to give values which would suit all conditions.

The curves given are calculated on the assumption that the injection water is raised to a temperature 5 deg. below that due to the vacuum, and that the condensate is cooled to 5 deg. above the injection or circulating-water-inlet temperature.

$$V = \frac{21 \cdot 8\,(t + 460) \times k}{P_2} + n_2,$$

where V = displacement of vacuum pump in cubic inches per min. per 1 lb. of steam condensed per hour.
P_2 = Pressure of the air (*see above*).
k = a constant, *see* Table 1.
n_2 = volume in cubic inches per min. of 1 lb. of condensed steam = ·462.
t = injection temperature + 5 deg.

Fig. 1. WET-AIR PUMPS JET CONDENSERS.

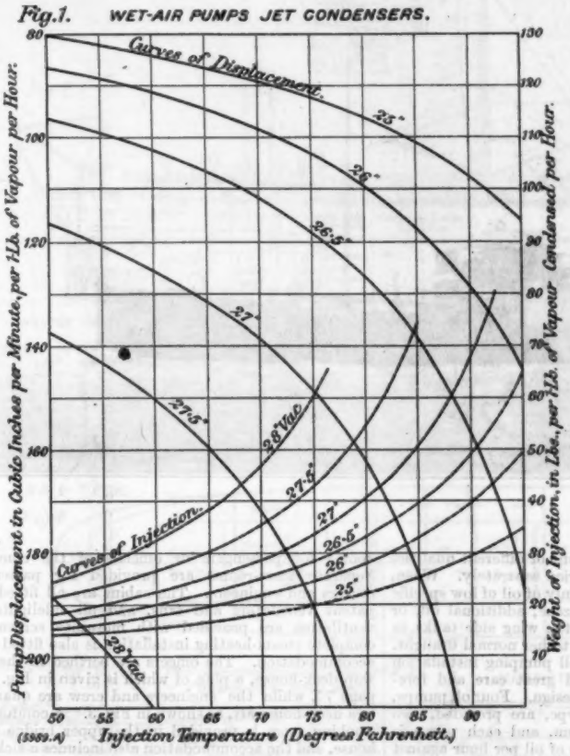


Fig. 2. DRY AIR PUMPS BAROMETER CONDENSERS.

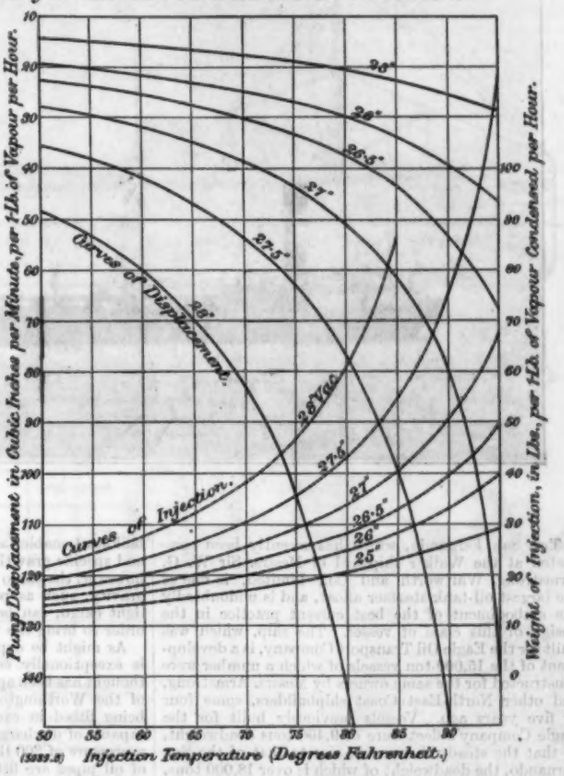
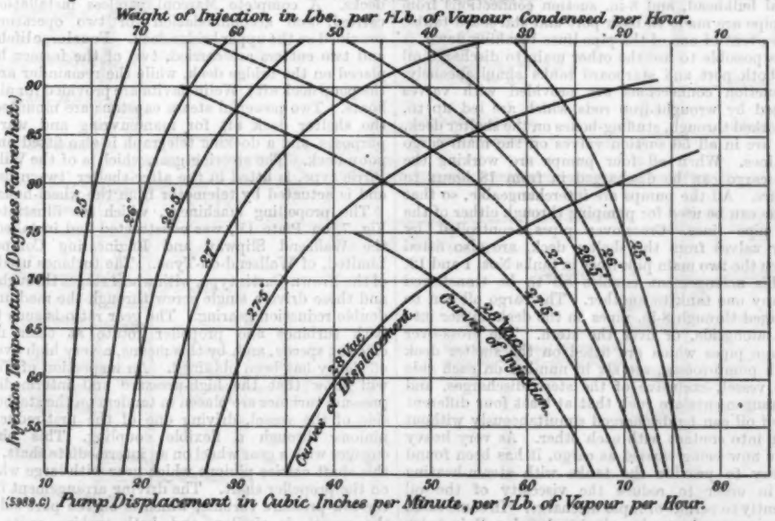


Fig. 3. WET-AIR PUMPS. SURFACE-CONDENSERS.



In the curves, k has been taken as ·0048, which is the value for triple-effet evaporators, and the displacements given by these curves must be multiplied by the co-efficients given in Table 2, if any other grouping of apparatus is required.

TABLE I.—*Values of "k" = $\frac{air}{steam}$ in pounds per hour.*

Type of apparatus.	"k"
Single effet	·0044
Double effet	·0046
Triple effet	·0048
Quadruple effet	·0059
Quintuple effet	·0062

TABLE II.—*Co-efficients for correcting displacement given in curves, for groupings other than Triple effet.*

Type of apparatus	Co-efficient.
Single effet	0·917
Double effet	0·958
Triple effet	1·000
Quadruple effet	1·23
Quintuple	1·29

The word "air" used in many places throughout the text is intended to cover all incondensible gases.

The writer has not intended to give a thorough scientific reasoning, nor to make allowances for all the minute phenomena connected with this subject, such scientific, or, one should say, academic, treatment, is certainly desirable in dealing with research work, or in training students, but the errors caused by the omission of these refinements in the formulæ are so small, as to be negligible, and as the points for the curves were all obtained by slide-rule aid, such differences have no doubt been fully covered, by the method of taking the next higher even figure.

BUSINESS WITH NORWAY.—The Norwegian Chamber of Commerce, London, Incorporated, Kingsway Chambers, Kingsway, London, W.C., states that it has been asked to acquaint British manufacturers and exporters with the fact that there is in Norway a strong feeling in favour of dealing with agents resident in Norway in preference to agents resident in one of the neighbouring countries.

OIL TANK STEAMER "SAN FERNANDO."

CONSTRUCTED BY SIR W. G. ARMSTRONG, WHITWORTH AND CO., LIMITED, NEWCASTLE-ON-TYNE.

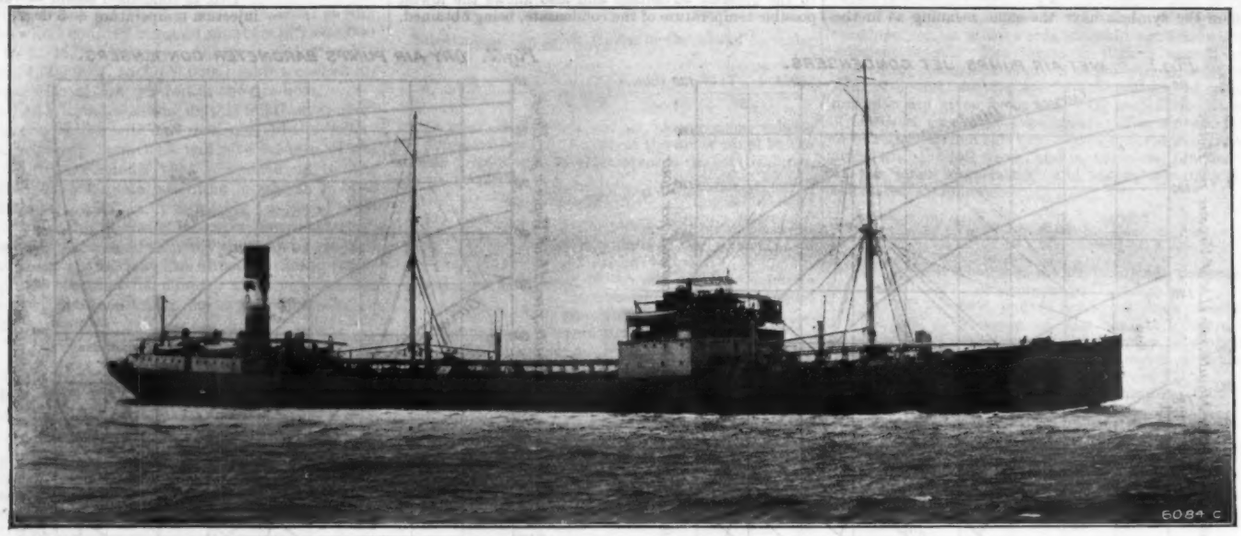


FIG. 1.

THE San Fernando, which has recently been completed at the Walker shipyard of Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, is one of the largest oil-tank steamer afloat, and is undoubtedly the embodiment of the best current practice in the design of this class of vessel. The ship, which was built for the Eagle Oil Transport Company, is a development of the 15,000-ton vessels of which a number were constructed for the same owners by Messrs. Armstrong, and other North-East Coast shipbuilders, some four or five years ago. Vessels previously built for the Eagle Company's fleet were of 9,400 tons deadweight, so that the steady increase in size to that of the San Fernando, the deadweight of which is over 18,000 tons, is very marked.

The illustrations on the present and opposite pages show the general appearance and the construction of the vessel, while on Plate IV we reproduce a photograph of the propelling machinery. It will be seen that the San Fernando is of the main deck and shelter-deck type, with the propelling machinery placed right aft. As is the case with all other large tankers owned by the Eagle and other companies, it is built on the Isherwood system of framing, which has certain advantages for vessels of this type. The scantlings, which are shown in the midship section, Fig. 6, are in many cases in excess of Lloyd's requirements, the thickness of the sheer strake and the shelter deck plating being considerably greater than stipulated by the society in order to give additional longitudinal stiffness. The overall length of the vessel is 547 ft., and the length between perpendiculars is 530 ft. The moulded breadth and depth are, respectively, 69 ft. and 42 ft. 3 in., while the height between the main deck and shelter deck is 15 ft. The extreme draught of water is 30 ft. 8½ in., and the deadweight at this draught is 18,550 tons.

As shown in Figs. 2 to 4, the main cargo space of the vessel is divided into 14 oil tanks, each of which is about 22 ft. 6 in. long, and these tanks are subdivided by a central longitudinal oil-tight bulkhead, which is continuous through the cofferdams and pump rooms. The foremost and aftermost tanks are used as oil fuel bunkers, and fuel oil can also be carried in the deep double bottom of the cargo hold forward, as shown in Fig. 2. Owing to the large size of this vessel, and to the different varieties of oil carried, it has been found necessary to provide two pump-rooms in the positions shown in Figs. 2 to 4, the positions being determined chiefly by the necessity for employing the shortest possible lengths of suction pipes. The transverse bulkheads forming these pump-rooms extend up to the shelter deck, so that the compartments act as cofferdams. Cofferdams are also provided between the oil-fuel tanks and the cargo tanks at each end of the vessel, and there is an additional cofferdam between tanks Nos. 8 and 9. The cargo tanks are thus divided into four self-contained groups, and the fact that they are, as already mentioned, divided by the longitudinal bulkhead enables a variety of oils of different qualities and specific gravities to be carried separately. When, however, the cargo consists mainly of oil of low specific gravity, such as petrol or benzene, additional oil, or light cargo, can be carried in the wing side tanks, in order to bring the vessel down to her normal draught.

As might be expected, the oil pumping installation is exceptionally complete, and great care and forethought has been applied to its design. Four oil pumps, of the Worthington duplex type, are provided, two being fitted in each pump-room, and each pump is capable of discharging 300 tons of oil per hour against a pressure of 200 lb. per square inch. Two main lines of oil pipes are fitted, one on each side of the longitudinal bulkhead, and 8-in. suction connections from each pipe are made to both port and starboard tanks. In the event of one of the pipe lines breaking down, it is thus possible to use the other main to discharge oil from both port and starboard tanks simultaneously. The suction connections are provided with valves actuated by wrought-iron rods which are led up to, and worked through, stuffing-boxes on the shelter deck. There are in all 56 suction valves on the main cargo pipe lines. When all four pumps are working the entire cargo can be discharged in from 18 hours to 20 hours. All the pumps are interchangeable, so that any one can be used for pumping through either of the main pipe lines. Cross-over pipes, controlled by master valves from the shelter deck, are also fitted between the two main pipe lines in tanks Nos. 1 and 12, and this arrangement enables oil to be transferred from any one tank to another. The cargo oil can be discharged through 8-in. pipes on the deck either into barges alongside, or over the stern. The cross-over discharge pipes which are fitted on the shelter deck at both pump-rooms, are six in number on each side of the vessel, exclusive of the stern discharges, and the arrangements are such that at least four different kinds of oil can be discharged simultaneously without coming into contact with each other. As very heavy oils are now being carried as cargo, it has been found necessary to provide the tanks with steam-heating pipes in order to reduce the viscosity of the oil sufficiently to permit of rapid discharge. In some cases the temperature has to be raised to 100 deg. F. in order to obtain a satisfactory flow. For this purpose, 2-in. coiled pipes are laid in the bottoms of the cargo tanks, and these are supplied with steam from the main boilers, the pressure being reduced to 120 lb. per square inch, by means of a reducing valve. Vapour pipes are fitted to the main cargo tanks, and these are all connected to a 5-in. main pipe, which is led up each of the masts to openings 30 ft. above the level of the deck. Short vapour pipes are also fitted to the wing tanks.

The accommodation provided in the San Fernando is exceptionally complete for a vessel of its class. Each officer has for himself a separate cabin, and, in addition to these, there are five double-berth state-rooms for passengers or officials of the company. Separate mess-rooms are provided for passengers, officers and engineers. The cabins are all fitted with patent ventilators and fans, and all sidelights and ventilators are provided with mosquito screens. A complete steam-heating installation is also fitted in all accommodation. The officers are berthed in the midship deck-house, a plan of which is given in Fig. 5, on page 77, while the engineers and crew are quartered in a deck-house aft, as shown in Fig. 3. A comfortable smoking room is provided in the upper bridge deck-house, and the accommodation also includes a sick bay. The refrigerating chamber, which is cooled by a plant of the CO_2 type, is fitted in the after shelter 'tween decks. A complete Marconi wireless installation is carried, and accommodation for two operators is provided on the upper bridge deck. Four large lifeboats and two cutters are carried, two of the former being placed on the bridge deck, while the remainder are on the poop deck aft; Welin davits are provided for all the boats. Two powerful steam capstans are mounted on the shelter deck aft for manœuvring and warping purposes, and a docking telegraph is also fitted on the poop deck. The steering gear, which is of the Wilson-Pirrie type, is fitted in the after shelter 'tween decks, and is actuated by telemotor from the wheel-house.

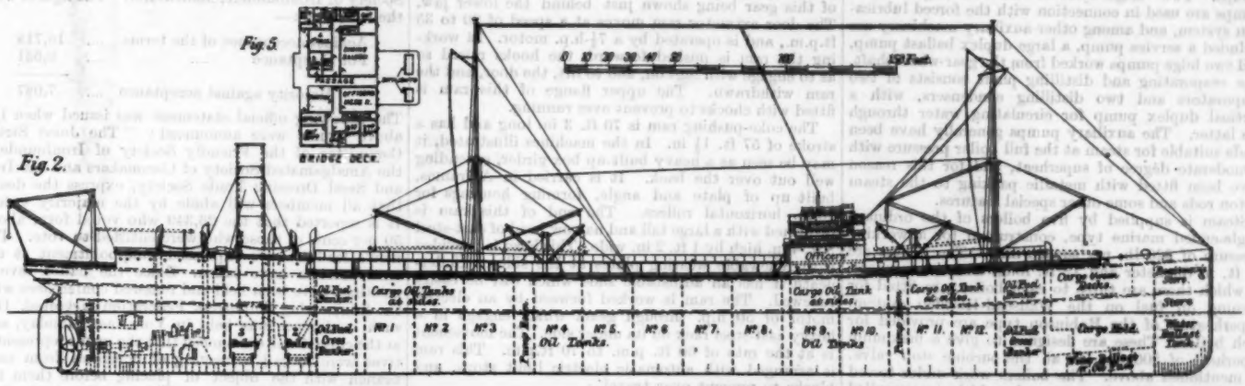
The propelling machinery, which we illustrate in Fig. 7, on Plate IV, was constructed and installed by the Wallsend Slipway and Engineering Company, Limited, of Wallsend-on-Tyne. The turbines used are of the Brown-Curtis type, with wheel stages throughout, and these drive a single screw through the medium of double reduction gearing. The gear ratio is such that both turbines and propeller rotate at their most efficient speeds, and, by this means, a very high overall efficiency has been obtained. An inspection of Fig. 7 will show that the high-pressure and intermediate-pressure turbines are placed in tandem on the starboard side of the vessel, driving one of the first-reduction pinions through a flexible coupling. This pinion engages with a gear wheel on an intermediate shaft, and this shaft carries pinions which gear with large wheels on the propeller shaft. The driving arrangement from the low-pressure turbine, which is on the port side of the vessel, is similar, and both turbine units are designed to give about equal power; the total shaft horse power, it should be mentioned, is about 4,300. For going astern, two turbines, working in series, are provided, and they are incorporated, respectively, with the intermediate and low-pressure ahead turbines. Dividing the astern turbines into two units in this way, besides increasing efficiency, has the additional advantage of providing greater immunity from complete breakdown, since, in an emergency, either of the turbines can be operated separately. Special attention has been given to the arrangement of pipes and valves for the main and emergency steam supply to the turbines, the shut off and manœuvring valves being supported from the forward bulkhead of the engine-

OIL TANK STEAMER "SAN FERNANDO."

CONSTRUCTED BY SIR W. G. ARMSTRONG, WHITWORTH AND CO., LIMITED, NEWCASTLE-ON-TYNE.

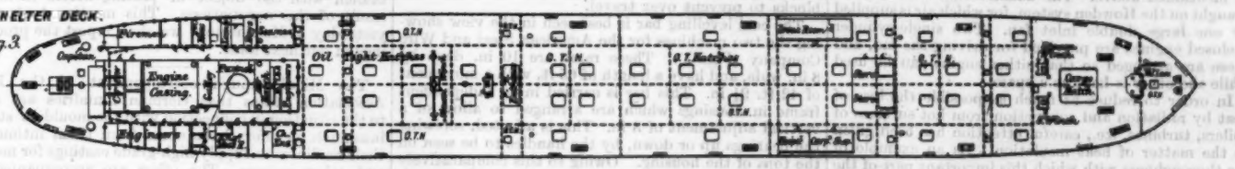
Fig. 5.

Fig. 2.



SHELTER DECK.

Fig. 3.



MAIN DECK.

Fig. 4.

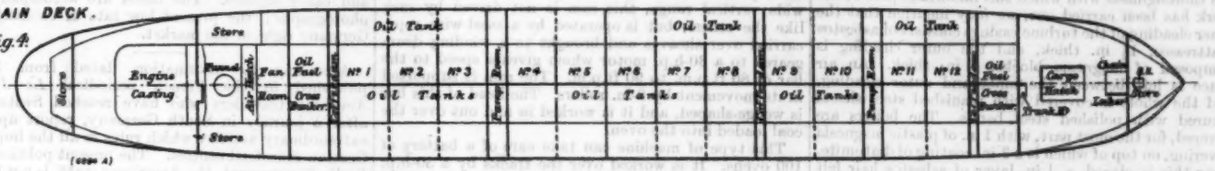
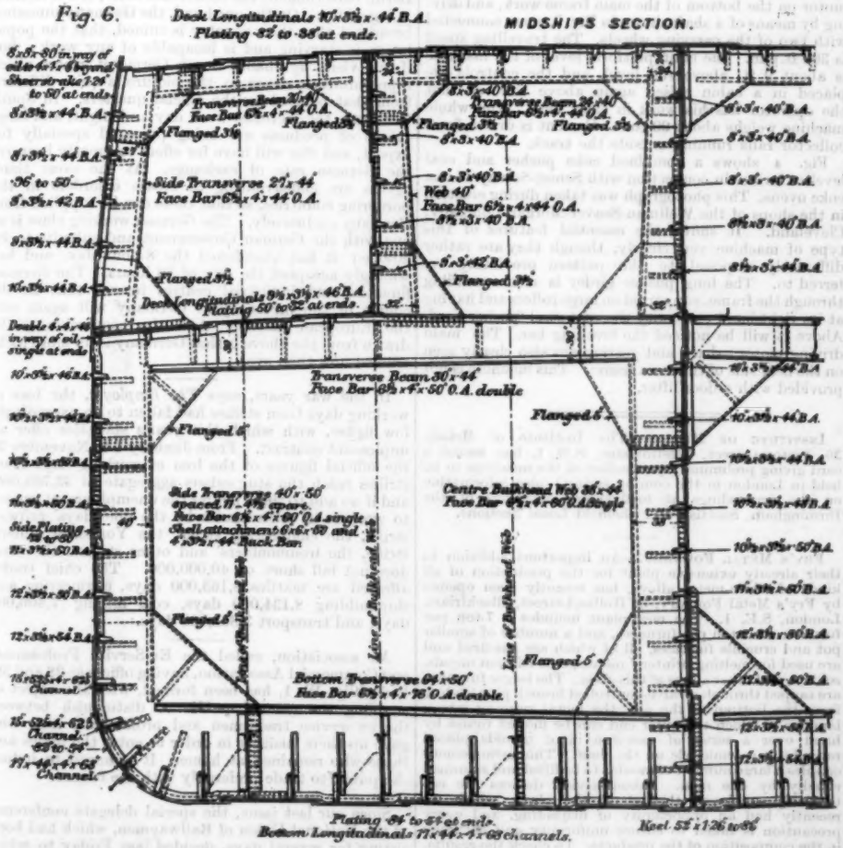


Fig. 6. MIDSHIPS SECTION.


Deck Longitudinals 10"x3½"x 44 B.A.
Plating 32" to 38" at ends.
Transverse Beam 30"x40"
Face Bar 6½"x 4"x 44" O.A.
Flanged 3½
Side Transverse 27"x 44"
Face Bar 6½"x 4"x 44" O.A.
Web 40"
Face Bar 6½"x 4"x 44" O.A.
Deck Longitudinals 9"x3½"x 46 B.A.
Plating 50" to 52" at ends.
Transverse Beam 30"x 44"
Face Bar 6½"x 4"x 50" O.A. double
Flanged 6"
Side Transverse 40"x 50"
spaced 11'-4½" apart.
Face Bar 6½"x 4"x 60" O.A. single
Shell attachment 6"x6"x 60 and
4"x3½"x 44" Back Bar.
Centre Bulkhead Web 36"x 44"
Face Bar 6½"x 4"x 60" O.A. single
Bottom Transverse 94"x 50"
Face Bar 6½"x 4"x 76" O.A. double
Plating 64" to 68" at ends.
Bottom Longitudinals 7"x 4"x 4"x 68 channels.
Keel 52"x 1.26" to 56"

room, and being placed high up near the level of the boiler stop valves. The starting platform is placed a few feet above the tank top, to suit the general arrangement of the machinery, the spindles from the manœuvring valves being led down and having hand wheels fitted at a convenient height for operating. The revolution counter and pressure gauges are grouped on a stand adjacent to the starting position. Emergency governors of the Proell type are fitted, and steam strainers are provided on the steam branches to the high-pressure ahead and astern turbines, and also in the connections to the low-pressure turbine.

Steam is supplied to the turbines at a pressure of 220 lb. per sq. in., with a maximum superheat of about 200 deg. F. at the stop valve, and the employment of superheated steam has necessitated the use of cast steel and phosphor bronze for the various details in contact with the steam at its highest pressure and temperature. The whole of the blading is of phosphor bronze material, and the stage wheels and spindles are made from ingot steel forgings in all cases. The gear wheels for both the first and second reduction trains have cast-iron bodies with toothed rims of forged ingot steel shrunk on; the pinions in all cases are made from nickel steel forgings. Lubrication of the gearing is effected by oil sprayed on to the teeth at the points of engagement, and the bearings of the gear wheels and pinion shafts, as well as those of the turbine spindles, are all fitted with forced lubrication. The main gear wheel shaft is of forged ingot steel, and is provided with a solid flanged coupling directly connected to the thrust shaft, as shown in the illustration, Fig. 7. The Michell thrust block is also clearly visible in this figure. A propeller of the built-up type, having four blades of manganese-bronze bolted to a cast-iron boss, is fitted.

The main condenser is of the Weir Uniflux type, designed to give a 27½ in. vacuum under ordinary service conditions with sea water at 85 deg. F. It may be interesting to mention that the arrangement of the machinery has enabled the condenser to be placed low down, but quite close to the low-pressure turbine, thus simplifying the drainage problem and also avoiding the use of the usual overhead exhaust connection. The circulating pump is of the centrifugal type, and is provided with two single cylinder enclosed engines, either of which can drive the pump at full power, so that one is kept as a stand-by; both pump and engines were supplied by Messrs. Drysdale and Co., Limited. The air pump fitted is of the Weir Dual type. The main feed pumps, two pairs of which are supplied, are of the vertical direct-acting type, and each pair is capable of dealing with the whole of the feed water required under ordinary service conditions. The feed is passed through a heater of the multiflow type, which utilises the exhaust steam from the auxiliary machinery. Both the feed heater and the feed pumps are of Messrs. Weir's manufacture. A main feed-water filter of the gravitation type is fitted, and an auxiliary filter is provided for the condensed steam from the cargo-heating coils and fuel-oil heaters. There is also an auxiliary condenser of the Weir Uniflux type to deal

with the exhaust from the whole of the auxiliary machinery, including the oil-cargo pumps. It is designed to give a vacuum of about 20 in., and is, of course, provided with the necessary air and circulating pumps. Two single-cylinder direct-acting vertical pumps are used in connection with the forced lubrication system, and among other auxiliary machinery are included a service pump, a large duplex ballast pump, and two bilge pumps worked from the gear-wheel shaft. The evaporating and distilling plant consists of two evaporators and two distilling condensers, with a vertical duplex pump for circulating water through the latter. The auxiliary pumps generally have been made suitable for steam at the full boiler pressure with a moderate degree of superheat, and for this reason have been fitted with metallic packing to the steam piston rods and some other special features.

Steam is supplied by five boilers of the ordinary single-ended marine type, constructed for a working pressure of 220 lb. per square inch. The boilers are 15 ft. in diameter and 12 ft. long, and the furnaces, of which there are three to each boiler, are fitted for burning oil fuel on the Wallsend-Howden system. Superheaters of the Robinson type are provided for each boiler. These are designed to give a maximum superheat of 200 deg. F. at the turbine stop valve, as mentioned above. The boilers work under forced draught on the Howden system, for which air is supplied by one large double inlet fan. Two single-cylinder enclosed engines are provided for driving the fan, and these are arranged so that either engine can be used while the other is kept as a spare.

In order to reduce as much as possible the loss of heat by radiation and convection from hot surfaces of boilers, turbines, &c., careful attention has been given to the matter of heat insulation. As an example of the thoroughness with which this important part of the work has been carried out, we may mention that the inner cleading of the turbine casings consists of asbestos mattresses, 1½ in. thick, and the outer cleading is composed of magnesia blocks, 2 in. thick. An air space is left between the inner and outer cleading, and the whole is covered with planished steel sheets secured with polished steel bands. The boilers are covered, for the most part, with 1 in. of plastic magnesia covering, on top of which is a 3-in. coating of diatomite. Over this is placed a ¼-in. layer of asbestos hair felt secured with galvanised wire netting, and the whole is covered in with 18-gauge galvanised iron sheeting held in place by galvanised iron straps. The lower portions of the boiler shells are covered with detachable asbestos mattresses, 3 in. thick, held in position by galvanised steel plating. The steam cylinders of the auxiliaries are carefully covered, as also are steam valve chests and all other exposed steam surfaces throughout the installation.

The whole of the machinery has been designed in accordance with the rules and regulations of Lloyd's Register, and it has been constructed under the supervision of Mr. Thomas McLellan, the superintendent for the owners. The trials took place in September last, when, in spite of very adverse weather, a mean speed of 11¼ knots was realised. It is anticipated that with normal weather conditions a speed of 12 knots will be obtained at full-load draught.

COKE OVEN MACHINES.

On Plates V and VI, which accompany this week's issue, there are given in Figs. 1 to 3, illustrations of some combination machines used in connection with the working of the Koppers type of coke oven. They were constructed by The Wellman-Seaver-Morgan Company, Cleveland, O., U.S.A., who are associated in this country with The Wellman Smith Owen Engineering Corporation, Limited, Kingsway, London, W.C.2. The latter have the sole manufacturing rights for Great Britain. These machines perform three operations, namely, removing the oven door, levelling the coal and pushing the product out of the oven when the coking process is completed. The machine is best seen in Figs. 1 and 3. Of these, Fig. 1 shows two coke pushers constructed for the American Steel and Wire Company for their coke plant at Cleveland, O., U.S.A., the other, Fig. 3, having been supplied to steelworks in Korea.

The machine, which is used to operate 16-ft. ovens, consists of a heavy steel frame, mounted on rails 28 ft. 6 in. apart. The frame is supported by two wheels on either side, whose centres are 14 ft. apart. The overall width is 20 ft. 6 in. The three operations are independent, but are all controlled from one cabin. Each employs a long ram which is worked out from the machine and is then withdrawn. The arrangement for extracting the doors is shown in Figs. 1 and 3. It consists of a ram with a travel of 9 ft. 5½ in. This is seen at the right-hand end of the machine in these figures. It is supported between 12-in. horizontal rollers carried in a steel framework, and is operated by motor-driven gears meshing with a rack on its lower flange. The ram is fitted with a jaw-like head pivotted upon it and fitted with spring buffing gear to take up the shock on striking the door. Working on the upper and lower extremities of the jaw are two hook levers, coupled together by links and capable of being raised and lowered by hand, the hand wheel of this gear being shown just behind the lower jaw. The door extractor ram moves at a speed of 30 to 35 ft.p.m., and is operated by a 7½-h.p. motor. In working the ram is pushed forward, the hooks raised so as to engage with lugs on, and to lift, the door, and the ram withdrawn. The upper flange of this ram is fitted with chocks to prevent over running.

The coke-pushing ram is 70 ft. 3 in. long and has a stroke of 57 ft. 1½ in. In the machines illustrated, it may be seen as a heavy built-up box girder, extending well out over the back. It is carried in A frames, built up of plate and angle, forming housings for 18-in. horizontal rollers. The end of this ram is furnished with a large tall and narrow head of cast-steel 8 ft. 4 in. high by 1 ft. 2 in. wide. This head is provided with renewable wearing plates at the sides. Underneath it has an adjustable shoe which can be easily renewed. The ram is worked forward by an electric motor of 50 h.p. through gears which engage in a heavy cast-steel rack on its under side. The movement is at the rate of 60 ft. p.m. to 70 ft.p.m. This ram is arranged with automatic electric limit stops, and blocks to prevent over travel.

The coal levelling bar is best seen in the view showing the two machines for the American Steel and Wire Company (Fig. 1). These rams are 10 in. deep by 8 in. wide, and have a length of 65 ft. with a movement of 42 ft. 9½ in. This bar is carried in an independent frame in housings which are arranged to allow of a vertical adjustment of 8 in. This is affected, screwing the bearings up or down, by the handles to be seen on the tops of the housing. Owing to this comparatively wide vertical range, this ram is not driven by rack like the others, but is operated by a steel wire rope, carried over sheaves and brought to a winding drum geared to a 30-h.p. motor which gives a speed to the bar of 80 ft.p.m. to 90 ft.p.m. The ram is supported in its movement by 9-in. rollers. The head of this bar is wedge-shaped, and it is worked in and out over the coal loaded into the oven.

This type of machine can take care of a battery of 100 ovens. It is worked over the tracks by a 30-h.p. motor on the bottom of the main frame work, and driving by means of a shaft shown in Fig. 3, gears connected with two of the carrying wheels. The travelling speed is 300 ft.p.m. The main platform level of the machine is about 9 ft. above rail level, and the controls are placed in a cabin raised again above this, so that the operator has his work in clear view. The whole machine weighs about 90 tons. Current is drawn from collector rails running outside the track.

Fig. 4 shows a combined coke pusher and coal leveller for use in connection with Semet-Solvay 15-ton coke ovens. This photograph was taken during erection in the shops of the Wellman-Seaver-Morgan Company, Cleveland. It shows the essential features of this type of machine very clearly, though they are rather differently disposed to the pattern previously referred to. The long pusher girder is seen extending through the frame, supported on large rollers and having at its right-hand extremity the cast-steel pusher-head. Above it will be noticed the levelling bar. The main driving motor, shaft and gearing are also clearly seen on the near side of the main frame. This machine is not provided with a door lifter.

INSTITUTE OF METALS.—The Institute of Metals, 36, Victoria-street, Westminster, S.W. 1, has issued a card giving preliminary particulars of the meetings to be held in London in the coming spring; also information on the proceedings at forthcoming meetings of the Birmingham, Scottish and Sheffield Local Sections.

FRY'S METAL FOUNDRY.—An important addition to their already extensive plant for the production of all kinds of white-metal alloys, has recently been opened by Fry's Metal Foundry, of Holland-street, Blackfriars, London, S.E. 1. The new plant includes a 7-ton pot furnace, six 2-ton pot furnaces, and a number of smaller pot and crucible furnaces, all of which are gas-fired and are used for melting printers' metals, anti-friction metals, solders, and other alloys of this class. The larger furnaces are tapped through a valve-controlled branch pipe leading from the bottom of the pot, the metal running into a launder of which the outer end can be moved round by hand over a series of cast-iron ingot moulds placed radially in a semicircle on the floor. This arrangement enables a large number of moulds to be filled and skimmed rapidly by one man. Labour-saving devices are extensively employed throughout the plant, which we recently had an opportunity of inspecting, and every precaution is taken to ensure uniformity and accuracy in the composition of the products. To check the results, however, each batch is analysed in the works laboratory, which is suitably equipped for both chemical and micrographical work. The firm's products include alloys for die casting, and they also supply die-cast machine and instrument parts.

INDUSTRIAL NOTES.

THE result of the moulders' ballot on the terms provisionally agreed to on the 2nd inst. was announced late on the 8th inst., at the offices of the Friendly Society of Ironfounders, Manchester. The figures were the following:—

Against acceptance of the terms	16,718
For acceptance	9,631
Majority against acceptance	7,087

The following official statement was issued when the above figures were announced: "The Joint Strike Committee of the Friendly Society of Ironfounders, the Amalgamated Society of Coremakers and the Iron and Steel Dressing Trade Society, express the desire that all members will abide by the majority vote." It is reported that the 26,349 who voted form about 50 per cent. of those who were entitled to vote. The men's leaders have expressed disappointment at the turn matters have taken. Since the ballot several meetings have been held and renewed conferences with the Engineering Employers' Federation suggested. One such conference was held in York last Monday, and at the close it was announced that the men's representatives were to call a meeting of delegates from each branch with the object of placing before them the result of the negotiations. This meeting took place yesterday in Manchester; we shall report the proceedings in our next issue.

The Middlesbrough correspondent of the Press Association states that German foundries are alive to the situation in connection with the moulders' strike, inasmuch as offers have come from them intimating their readiness to supply high-grade castings for motors and other engines. The offers are accompanied by photographs; the present low rate of exchange puts Germany right in the market.

According to information dated from Zurich, published in the French periodical *Le Journal*, American travellers who have reached Switzerland, after a journey in South Germany, report upon the extraordinary activity which rules in all the important German industrial centres. The present politics of the Berlin Government, the Americans state, is not lacking in ingenuity. On the one hand, the Germans announce broadcast that their country is ruined, that the population is starving and is incapable of any work; but if one visits by chance South Germany, where allied representatives never go, the picture is quite different from that painted by the official quarters. In South Germany, the factories work day and night, and large stocks of products are being prepared specially for export, and this will have for effect to greatly improve the German rate of exchange. At the same time, agents are endeavouring to create disorders in the bordering countries, so that these can be supplied from Germany exclusively. The German working class is at one with the German Government and submits to its advice; it has abandoned the 8-hour day, and has willingly accepted the day of 10 hours. The German financial and industrial centres foresee that in the course of the present year Germany will again rule the European market. And the conclusion to be drawn from the above is that Germany is no more to be trusted now than ever.

In the war years, says *The Employer*, the loss of working days from strikes had fallen to an exceedingly low figure, with which this year's statistics offer an unpleasant contrast. From January 1 to November 30 the official figures of the loss of working days from strikes reach the stupendous aggregate of 32,769,000, and if we add to these figures the unemployment caused to workers in other trades by the nine days' railway strike, the engineering strike, the Yorkshire miners' strike, the ironmoulders' and other strikes, the total does not fall short of 40,000,000. The chief trades affected are textiles 8,163,000 days, engineering and shipbuilding 8,134,000 days, coal mining 7,406,000 days, and transport 3,868,000 days.

An association, called the Ex-Service Professional and Commercial Association, having offices at 38 and 39, Piccadilly, W. 1, has been formed, with the object of enabling the general public to distinguish between the ex-service tradesmen and professional men who gave up their business in order to enter the forces and those who remained at home. It is hoped to induce the public to trade preferably with the former.

Since our last issue, the special delegate conference of the National Union of Railwaymen, which had been sitting for several days, decided last Friday to reject the Government's proposals, and sent them back to the Government. The delegates have since continued in session at Unity House awaiting an answer from the Government. The general terms offered to the

EXPERIMENTS ON THE AMOUNT OF STEAM USED BY STEAM JETS.

(*For Description, see Page* 71.)

TABLE I.—HAND FIRING.

Type A.—Consists essentially of seven jets of approximately ¼-in. holes on ¼-in. steam pipe per furnace (that is, 14 jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces. Often also has in addition one jet of approximately ¼-in. hole on ¼-in. steam pipe per furnace (that is, two jets on "Lancashire" boilers) over the top of the fires. All jets on full boiler pressure and steam supply regulated with a hand valve.

The average steam consumption on six plants fitted with this type of steam-jet apparatus is about 7·6 per cent. of the steam production, divided as follows :—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	1 Lancashire ..	4,982	61	215·0	4·3	1,000	1,500	43·0	64·5
2	5 Lancashire ..	4,331	95	277·2	6·4	9,500	14,250	608·0	912·0
3	2 Lancashire ..	4,544	75	227·2	5·0	1,950	2,925	97·5	146·25
4	2 Lancashire ..	6,126	68	520·7	8·5	3,000	4,500	255·0	382·5
5	2 Lancashire ..	1,698	76	172·5	10·2	750	1,125	76·5	114·75
6	5 Lancashire ..	4,995	108	636·0	12·7	4,000	6,000	508·0	762·0

Type B.—Consisting essentially of eight jets of approximately ¼-in. holes on ¾-in. steam pipe per furnace (that is, 16 jets per boiler on "Lancashire" boilers). Jets situated under the back of the furnaces, and pressure at jets generally reduced to 20 lb. to 40 lb. by means of a reducing valve. Steam supply also regulated with a hand valve.

The average steam consumption on four plants fitted with this type of steam-jet apparatus is about 4·5 per cent. of the steam production divided as follows :—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	2 Lancashire ..	6,500	20	112·0	1·7	6,000	9,000	102·0	153·0
2	1 Lancashire ..	7,500	40	200·0	2·6	2,500	3,750	65·0	97·5
3	1 Lancashire ..	6,857	30	240·0	3·5	2,000	3,000	70·0	105·0
4	3 Lancashire ..	4,311	35	584·0	13·5	4,900	7,350	661·5	992·25

Type C.—Consists essentially of two jets of approximately $\frac{7}{16}$-in. to $\frac{9}{16}$-in. holes on ¾-in. steam pipe per furnace (that is, four jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces on full boiler pressure, and steam supply regulated with a hand valve.

The average steam consumption on three plants fitted with this type of steam-jet apparatus is about 7·3 per cent. of the steam production, divided as follows :—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	2 Lancashire ..	3,480	55	34·8	1·0	1,700	2,550	17·0	25·5
2	3 Lancashire ..	3,813	148	304·0	8·0	6,500	9,750	520·0	780·0
3	1 Lancashire ..	2,838	71	408·6	14·4	1,034	1,551	148·9	223·35

Type D.—Consists essentially of either three or four jets of approximately $\frac{7}{16}$-in. to ½-in. holes on ½-in. or ¾-in. steam pipe per furnace (that is, six or eight jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces. Generally the boiler pressure is reduced to some extent, but not always, and the steam supply is regulated with a hand valve.

The average steam consumption on 18 plants fitted with this type of steam-jet apparatus is about 6·3 per cent. of the steam production, divided as follows :—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	6 Lancashire ..	5,590	76	190·0	3·4	21,696	32,544	737·6	1,106·4
2	2 Lancashire ..	6,250	75	262·5	4·2	2,500	3,750	105·0	157·5
3	2 Lancashire ..	3,159	40	189·5	6·0	2,050	3,075	123·0	184·5
4	3 Lancashire ..	4,770	100	322·0	6·75	3,750	5,625	379·7	569·5
5	2 Lancashire ..	4,530	72	317·1	7·0	3,500	5,250	245·0	367·5
6	1 Lancashire ..	5,404	152	486·3	9·0	1,750	2,625	157·5	236·2

TABLE I.—HAND FIRING—(*continued*)

Type H.—Consists essentially of four jets of approximately $\frac{7}{16}$-in. holes on ¼-in. steam pipe (that is, eight jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces on full boiler pressure and steam supply regulated with a hand valve. The average steam consumption on two plants fitted with this type of steam-jet apparatus is about 7·7 per cent. of the steam production, divided as follows :—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	5 Lancashire ..	5,852	80	376·0	6·4	12,400	18,600	793·6	1,190·4
2	1 Lancashire ..	4,869	64	450·0	9·2	2,000	3,000	184·0	276·0

Type I.—Consists essentially of three jets of approximately $\frac{7}{16}$-in. holes on ¼-in. steam pipe (that is, six jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces on full boiler pressure, and steam supply regulated with a hand valve. The average steam consumption on three plants fitted with this type of steam-jet apparatus is about 4·4 per cent. of the steam production, divided as follows :—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	2 Lancashire ..	5,093	73	166·0	3·2	2,800	4,200	89·6	134·4
2	2 Lancashire ..	6,066	80	227·5	3·75	3,800	5,700	213·75	320·6
3	2 Lancashire ..	4,879	89	370·8	7·6	1,925	2,887·5	146·3	219·4

Type J.—Consists essentially of three jets of approximately ¼-in. hole on ¾-in. steam pipe (that is, six jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnace on full boiler pressure and steam supply regulated with a hand valve.

Boiler Plant.		Actual Net Weight of Steam Evaporated in the Plant, Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	2 Lancashire ..	3,173	62	438·8	13·25	4,000	6,000	610·0	915·0

Type K.—Consisting of forms of steam-jet apparatus made on the spot by works' engineers to their own ideas, that is, a type not on sale in the open market. They are merely variations of the various types already described. The average steam consumption on six plants fitted with this type of steam-jet apparatus is about 5·9 per cent. of the steam production, divided as follows :—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	6 Lancashire ..	5,590	76	190·0	3·4	21,696	32,544	737·6	1,106·4
2	2 Lancashire ..	6,250	75	262·5	4·2	2,500	3,750	105·0	157·5
3	2 Lancashire ..	3,159	40	189·5	6·0	2,050	3,075	123·0	184·5
4	3 Lancashire ..	4,770	100	322·0	6·75	3,750	5,625	379·7	569·5
5	2 Lancashire ..	4,530	72	317·1	7·0	3,500	5,250	245·0	367·5
6	1 Lancashire ..	5,404	152	486·3	9·0	1,750	2,625	157·5	236·2

TABLE II.—MECHANICAL FIRING (SPRINKLING TYPE STOKERS).

Type A.—Consists essentially of a varying number of jets, 20 to 37, of approximately $\frac{7}{16}$-in. to ½-in. holes on ½-in. steam pipe per furnace (that is, 40 to 74 jets per boiler on "Lancashire" boilers). Jets situated under the back of the furnaces on full boiler pressure, and steam supply regulated with a hand valve, which is generally very little open. The average steam consumption on 25 plants fitted with this type of steam-jet apparatus is about 5 per cent. of the production, divided as follows :—

Boiler Plant.		Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum.		Corresponding Annual Coal Bill used only by the Steam Jets.	
Ref. No.	Type and Number of Boilers on Plant.					Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.	Tons.	£, Taking Coal at Average Price of 30*s.* per Ton.
					per cent.		£		£
1	2 Lancashire ..	5,000	80	250·0	5·0	2,000	3,000	100·0	150·0
2	2 Lancashire ..	5,000	80	250·0	5·0	2,000	3,000	100·0	150·0
3	2 Lancashire ..	5,000	80	250·0	5·0	2,000	3,000	100·0	150·0
4	2 Lancashire ..	5,000	80	250·0	5·0	2,000	3,000	100·0	150·0
5	2 Lancashire ..	5,000	80	250·0	5·0	2,000	3,000	100·0	150·0

Ref. No.	Type and Number of Boilers on Plant.	Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum. Tons.	Coal Bill of the Plant per Annum. £, Taking Coal at Average Price of 30s. per Ton.	Corresponding Annual Coal Bill used only by the Steam Jets. Tons.	Corresponding Annual Coal Bill used only by the Steam Jets. £, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	1 Lancashire ..	4,869	64	168·0	3·4	2,000	3,000	68·0	102·0
2	5 Lancashire ..	3,618	102	137·4	3·8	4,200	6,300	159·6	239·4
3	5 Lancashire ..	9,381	134	372·4	3·97	19,000	28,500	754·3	1,141·5
4	2 Lancashire ..	8,372	152	348·0	4·1	4,500	6,750	184·5	276·7
5	6 Lancashire ..	7,326	112	307·7	4·2	17,400	26,100	730·8	1,096·2
6	3 Lancashire ..	8,035	151	415·4	5·17	6,050	9,075	312·8	469·2
7	2 Lancashire ..	4,580	40	249·3	5·40	3,200	4,800	269·2	403·8
8	6 Lancashire ..	6,341	88	364·6	5·75	15,600	23,400	897·0	1,345·5
9	5 Lancashire ..	4,331	95	277·1	6·4	9,500	14,250	608·0	912·0
10	3 Lancashire ..	2,754	68	179·0	6·5	3,400	5,100	221·0	331·5
11	1 Lancashire ..	4,585	88	316·4	6·9	1,250	1,875	86·2	129·3
12	9 Lancashire ..	4,297	70	339·4	7·9	22,000	33,000	1,738·0	2,607·0
13	1 Lancashire ..	3,929	85	369·3	9·4	1,200	1,800	112·8	169·2
14	4 Lancashire ..	4,995	108	492·0	9·8	16,000	24,000	1,568·0	2,352·0
15	1 Lancashire ..	4,311	72	426·0	9·9	2,450	3,675	242·5	363·7
16	1 Lancashire ..	3,838	54	286·6	10·1	1,450	2,175	146·5	219·6
17	1 Lancashire ..	3,472	88	371·5	10·7	1,375	2,063	147·1	220·6
18	4 Lancashire ..	3,561	87	470·0	13·2	6,330	9,495	835·5	1,253·2

Type E.—Consists essentially of two jets of approximately $\frac{5}{16}$-in. holes on $\frac{1}{2}$-in. steam pipe per furnace (that is, four jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces. Full boiler pressure on jets and the steam supply regulated with a hand valve.

The average steam consumption on seven plants fitted with this type of steam-jet apparatus is about 8·1 per cent. of the steam production, divided as follows :—

Ref. No.	Type and Number of Boilers on Plant.	Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum. Tons.	Coal Bill of the Plant per Annum. £, Taking Coal at Average Price of 30s. per ton.	Corresponding Annual Coal Bill used only by the Steam Jets. Tons.	Corresponding Annual Coal Bill used only by the Steam Jets. £, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	2 Lancashire ..	5,418	32	189·6	3·5	1,750	2,625	61·25	91·8
2	3 Lancashire ..	1,786	70	66·0	3·8	3,000	4,500	114·0	171·0
3	1 Lancashire ..	4,856	64	266·0	5·5	1,500	2,250	82·5	123·7
4	2 Lancashire ..	4,157	44	261·9	6·3	2,200	3,300	138·6	207·9
5	3 Lancashire .. / 5 tubular ..	9,728	120	1,001·9	10·3	35,000	52,500	3,605·0	5,407·5
6	4 tubular ..	7,609	119	798·6	10·5	9,000	13,500	945·0	1,417·5
7	2 Lancashire ..	4,761	92	520·0	10·9	3,000	4,500	327·0	490·5

Type F.—Consists essentially of two jets of approximately $\frac{1}{2}$-in. holes on $\frac{1}{2}$-in. steam pipe per furnace (that is, four jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces on full boiler pressure, and steam supply regulated with a hand valve.

The average steam consumption on two plants fitted with this type of steam-jet apparatus is about 3·2 per cent. of the steam production, divided as follows :—

Ref. No.	Type and Number of Boilers on Plant.	Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum. Tons.	Coal Bill of the Plant per Annum. £, Taking Coal at Average Price of 30s. per Ton.	Corresponding Annual Coal Bill used only by the Steam Jets. Tons.	Corresponding Annual Coal Bill used only by the Steam Jets. £, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	1 Lancashire ..	4,165	76	104·0	2·49	2,650	3,975	65·9	98·8
2	2 Lancashire ..	5,898	82	221·2	3·75	3,200	4,800	120·0	180·8

Type G.—Consists essentially of four jets of approximately $\frac{5}{16}$-in. holes on $\frac{1}{2}$-in. steam pipe per furnace (that is, eight jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnaces on full boiler pressure and the steam supply regulated with a hand valve.

The average steam consumption on two plants fitted with this type of steam-jet apparatus is about 5 per cent. of the steam production, divided as follows :—

Ref. No.	Type and Number of Boilers on Plant.	Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum. Tons.	Coal Bill of the Plant per Annum. £, Taking Coal at Average Price of 30s. per ton.	Corresponding Annual Coal Bill used only by the Steam Jets. Tons.	Corresponding Annual Coal Bill used only by the Steam Jets. £, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	3 Lancashire ..	4,798	113	233·75	4·8	4,600	6,900	220·8	331·2
2	1 Lancashire ..	4,869	64	257·6	5·29	2,000	3,000	105·8	158·7

TABLE II.—MECHANICAL FIRING (SPRINKLING TYPE STOKERS).

Type A.—Consists essentially of a varying number of jets, 20 to 37, of approximately $\frac{5}{16}$-in. to $\frac{1}{2}$-in. holes on $\frac{1}{2}$-in. steam pipe per furnace (that is, 40 to 74 jets per boiler on "Lancashire" boilers). Jets situated under the back of the furnaces on full boiler pressure, and steam supply regulated with a hand valve, which is generally very little open. The average steam consumption on 25 plants fitted with this type of steam-jet apparatus is about 5 per cent. of the production, divided as follows :—

Ref. No.	Type and Number of Boilers on Plant.	Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum. Tons.	Coal Bill of the Plant per Annum. £, Taking Coal at Average Price of 30s. per Ton.	Corresponding Annual Coal Bill used only by the Steam Jets. Tons.	Corresponding Annual Coal Bill used only by the Steam Jets. £, Taking Coal at Average Price of 30s. per Tons..
					per cent.		£		£
1	2 Lancashire ..	5,057	101	25·3	0·50	3,750	5,625	18·7	28·0
2	2 Lancashire ..	4,735	110	99·4	2·10	3,340	5,010	70·1	105·1
3	2 Lancashire ..	9,190	159	194·0	2·10	3,750	5,625	78·7	118·0
4	2 Lancashire ..	7,062	110	176·5	2·50	4,480	6,720	112·0	168·0
5	2 Lancashire ..	3,016	74	80·0	2·60	3,775	5,662	98·1	147·1
6	2 Lancashire ..	3,073	112	82·9	2·70	1,385	2,077	37·4	56·1
7	3 Lancashire ..	8,193	159	225·3	2·75	4,750	7,125	195·9	293·8
8	3 Lancashire ..	3,257	101	89·5	2·75	1,675	2,512	46·0	69·0
9	1 Lancashire ..	8,734	103	262·0	3·0	1,500	2,250	45·0	67·5
10	1 Lancashire ..	7,457	100	238·6	3·2	1,000	1,500	32·0	48·0
11	2 Lancashire ..	11,146	157	362·4	3·25	4,750	7,125	154·4	231·6
12	2 Lancashire ..	4,305	122	149·6	3·4	2,400	3,600	81·6	122·4
13	5 Lancashire ..	5,316	92	186·0	3·5	5,500	8,250	192·5	288·7
14	3 Lancashire ..	3,182	74	111·4	3·50	2,500	3,750	87·5	131·2
15	3 Lancashire ..	2,555	75	89·4	3·50	5,500	8,250	192·5	288·7
16	7 Lancashire ..	4,907	62	176·6	3·6	23,200	34,800	835·2	1,252·8
17	3 Lancashire ..	5,833	110	218·7	3·75	7,000	10,500	262·5	393·7
18	6 Lancashire ..	5,366	86	203·9	3·8	14,250	21,375	541·5	812·2
19	2 Lancashire ..	5,789	104	238·6	4·12	3,300	4,950	135·9	203·8
20	4 Lancashire ..	7,350	78	360·0	4·9	6,500	9,750	318·5	477·7
21	2 Lancashire ..	3,368	141	180·0	5·3	3,000	4,500	159·0	238·5
22	4 Lancashire ..	8,769	136	494·2	7·3	5,940	8,910	433·6	650·4
23	1 Lancashire ..	3,929	85	369·3	9·40	1,200	1,800	112·8	169·2
24	3 Lancashire ..	4,311	77	581·9	13·50	4,900	7,350	661·5	992·2
25	7 Lancashire ..	4,343	67	655·8	15·10	21,000	31,500	3,171·0	4,756·0

Type B.—Consists essentially of six to eight jets of approximately $\frac{5}{16}$-in. to $\frac{1}{2}$ in. holes on $\frac{1}{2}$-in. steam pipe per furnace (that is, 12 to 16 jets per boiler on "Lancashire" boilers). Jets situated under the front of the furnace on full boiler pressure, and the steam supply regulated with a hand valve, which is generally full open. The average steam consumption on 16 plants fitted with this type of steam-jet apparatus is about 5·25 per cent. of the production, divided as follows :—

Ref. No.	Type and Number of Boilers on Plant.	Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum. Tons.	Coal Bill of the Plant per Annum. £, Taking Coal at Average Price of 30s. per ton.	Corresponding Annual Coal Bill used only by the Steam Jets. Tons.	Corresponding Annual Coal Bill used only by the Steam Jets. £, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	2 Lancashire ..	7,054	147	38·8	0·55	3,250	4,875	17·8	26·8
2	2 Lancashire ..	8,487	80	252·0	2·96	8,000	12,000	236·8	355·2
3	3 Lancashire ..	6,382	93	197·8	3·10	7,500	11,250	232·5	348·7
4	3 Lancashire ..	4,659	58	149·0	3·20	3,500	5,250	112·0	168·0
5	1 Lancashire ..	7,463	116	410·4	3·50	2,750	4,125	151·2	226·8
6	2 Lancashire ..	3,598	86	136·7	3·80	2,000	3,000	76·0	114·0
7	3 Lancashire ..	6,073	88	261·1	4·30	6,500	9,750	279·5	419·2
8	6 Lancashire ..	6,229	127	270·3	4·34	17,900	26,850	776·8	1,165·3
9	2 Lancashire ..	2,212	42	98·8	4·47	1,750	2,625	78·2	117·3
10	3 Lancashire ..	6,255	135	308·3	4·93	5,750	8,625	283·5	425·2
11	3 Lancashire ..	6,046	154	359·7	5·95	6,900	10,350	410·5	615·7
12	3 Lancashire ..	5,943	108	371·4	6·25	7,500	11,250	468·7	703·0
13	4 Lancashire ..	6,915	100	449·4	6·50	5,500	8,250	357·5	536·2
14	2 Lancashire ..	5,601	130	497·5	8·90	5,500	8,250	489·5	734·2
15	4 Lancashire ..	6,316	80	568·4	9·0	8,250	12,375	742·5	1,114·2
16	2 Lancashire ..	7,002	148	700·2	10·0	3,000	4,500	300·0	450·0

Type C.—Consists essentially of 22 jets of approximately $\frac{5}{16}$-in. holes on $\frac{1}{2}$-in. steam pipe per furnace (that is, 44 jets per boiler on "Lancashire" boilers). Jets situated under the furnaces at the back on full boiler pressure. Steam supply regulated with a hand valve, which is generally kept very little open. The average steam consumption on seven plants fitted with this type of steam-jet apparatus is about 5 per cent. of the production, divided as follows :—

Ref. No.	Type and Number of Boilers on Plant.	Actual Net Weight of Steam Evaporated on the Plant Calculated per Boiler per Hour, in Lb.	Actual Steam Pressure on the Jets, Lb. per Sq. In.	Actual Net Weight of Steam Used by the Jets, Calculated per Boiler per Hour, in Lb.	Corresponding Percentage of the Total Steam Production of the Plant, Used by the Jets.	Coal Bill of the Plant per Annum. Tons.	Coal Bill of the Plant per Annum. £, Taking Coal at Average Price of 30s. per Ton.	Corresponding Annual Coal Bill used only by the Steam Jets. Tons.	Corresponding Annual Coal Bill used only by the Steam Jets. £, Taking Coal at Average Price of 30s. per Ton.
					per cent.		£		£
1	5 Lancashire ..	7,557	101	377·8	2·50	7,850	11,775·0	392·5	588·7
2	2 Lancashire ..	3,167	93	118·7	3·40	1,375	2,062·5	51·6	77·4
3	3 Lancashire ..	4,376	59	153·2	3·50	3,400	5,100·0	119·0	178·5
4	6 Lancashire ..	6,144	61	258·0	4·20	7,400	11,100·0	310·8	466·2
5	2 Lancashire ..	5,754	82	252·0	4·40	3,250	4,875·0	143·0	214·5
6	3 Lancashire ..	6,421	51	346·7	5·40	5,245	7,867·5	283·2	424·8
7	2 Lancashire ..	2,848	96	489·8	17·20	1,550	2,325·0	266·6	399·9

DOUBLE CROSS

DOUBLE-GEARED TURBINE PROPELLING MACHINERY FOR OIL-TANK STEAMER "SAN FERNANDO."

CONSTRUCTED BY THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, LIMITED, ENGINEERS, WALLSEND-ON-TYNE.

(*For Description, see Page* 76.)

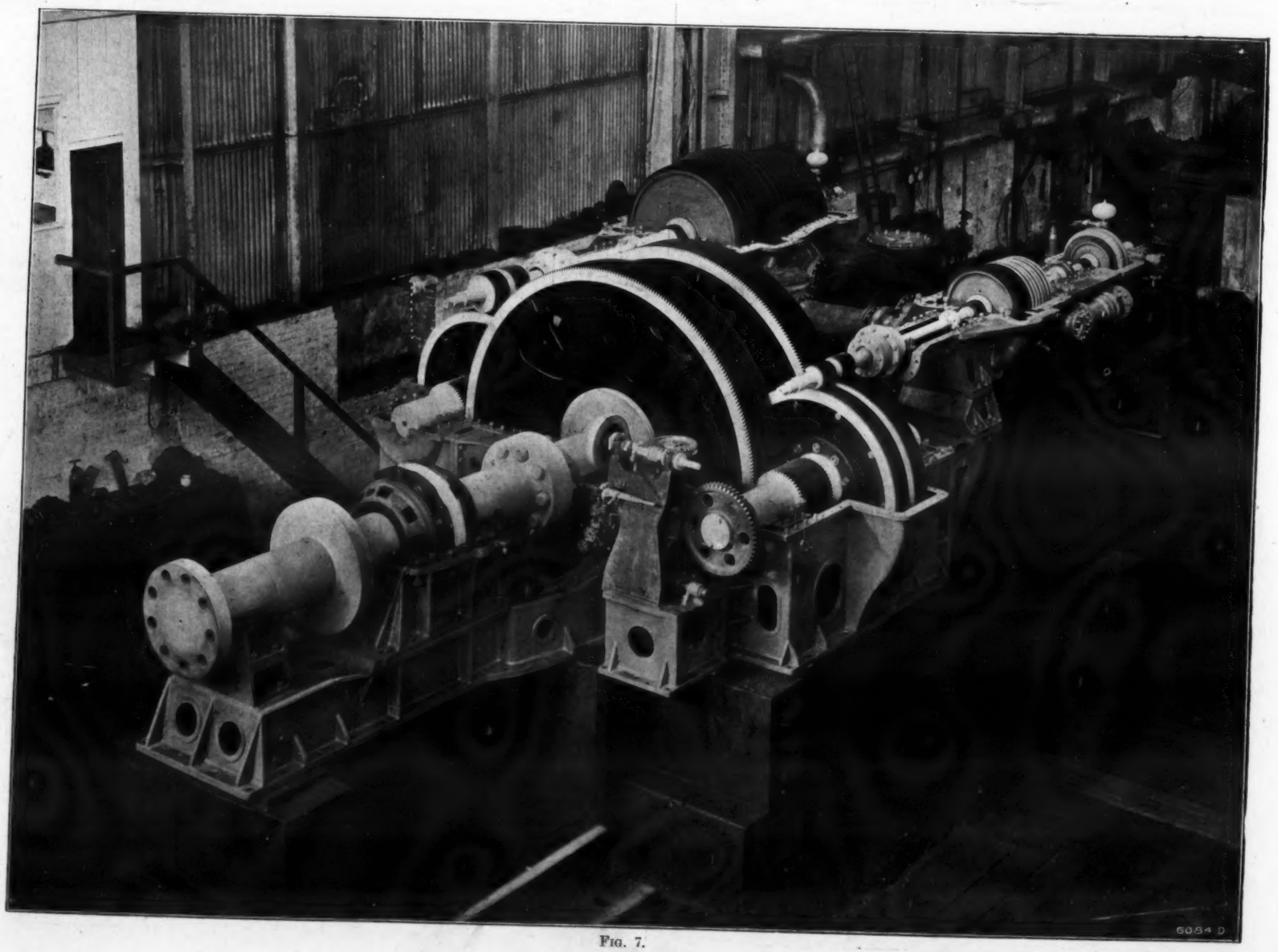


FIG. 7.

(*To face page* 78.)

COKE-OVEN MACHINES.

CONSTRUCTED BY THE WELLMAN-SEAVER MORGAN COMPANY, ENGINEERS, CLEVELAND, O., U.S.A.

(*For Description, see Page* 78.)

FIG. 1. COKE PUSHERS FOR THE AMERICAN STEEL AND WIRE COMPANY'S WORKS, CLEVELAND, OHIO, U.S.A.

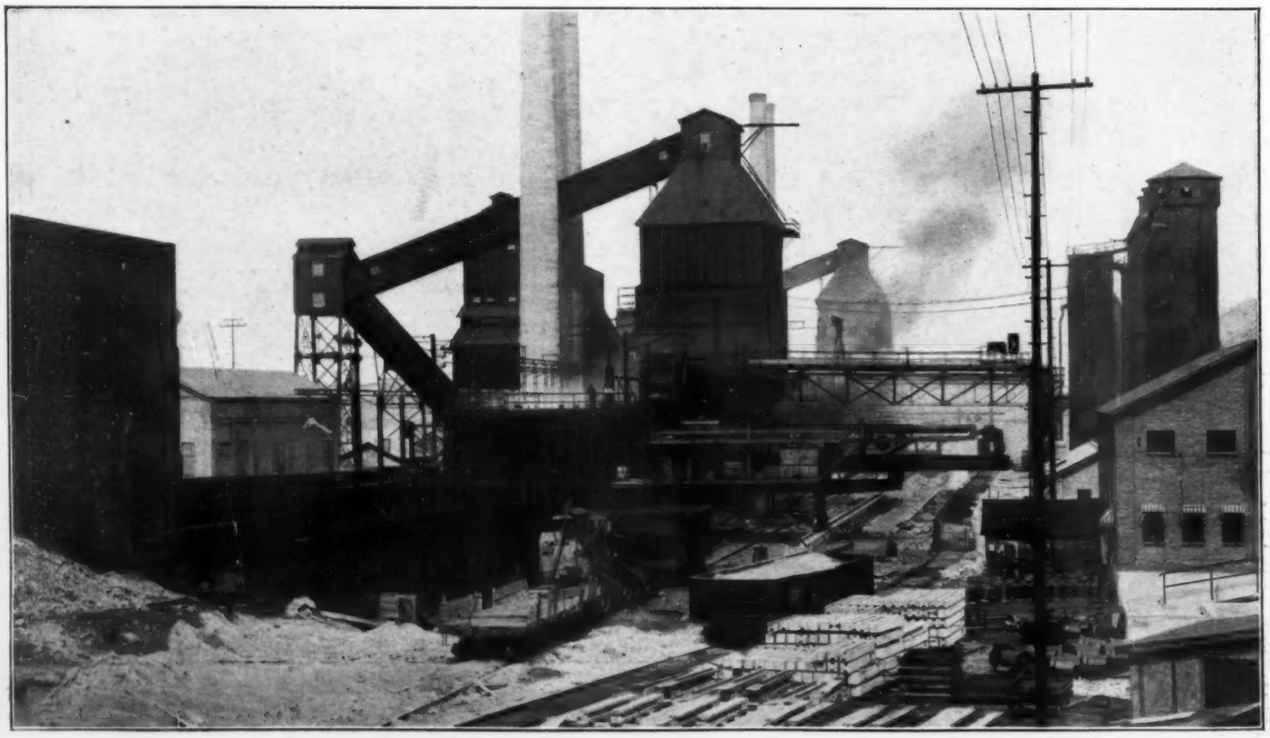


FIG. 2. COKE PUSHER FOR KOPPER BY-PRODUCT OVENS.

COKE-OVEN MACHINES.

CONSTRUCTED BY THE WELLMAN-SEAVER-MORGAN COMPANY, ENGINEERS, CLEVELAND, O., U.S.A.

(*For Description, see Page* 78.)

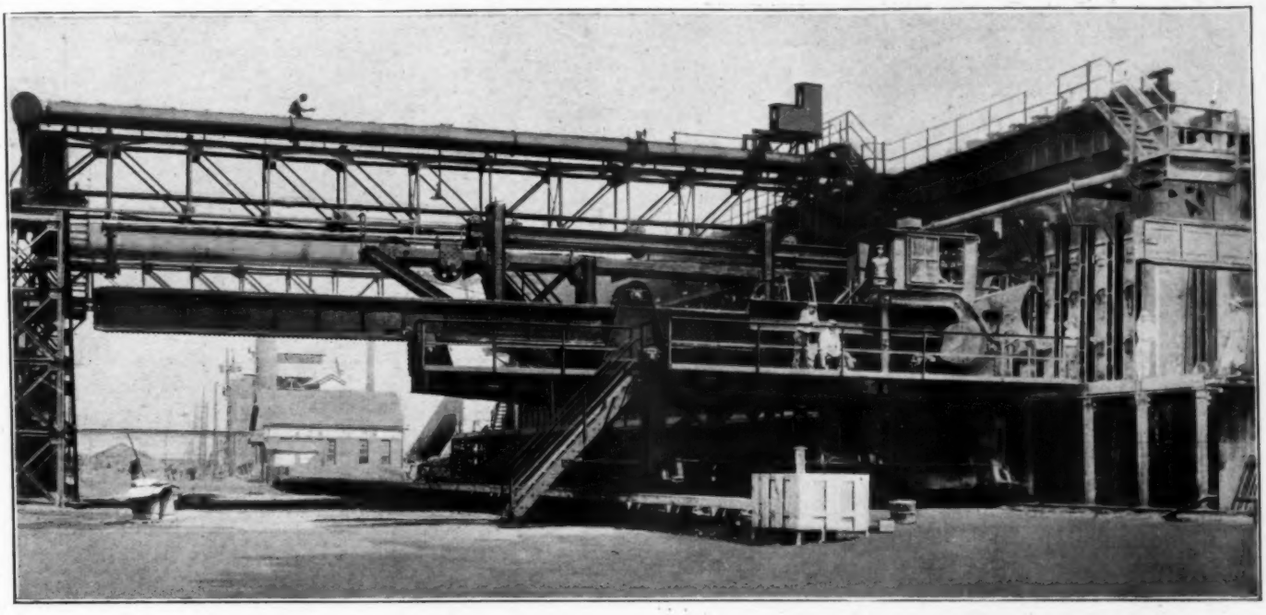


FIG. 3. COKE PUSHER, COAL LEVELLER, AND DOOR EXTRACTOR AT STEEL WORKS IN KOREA.

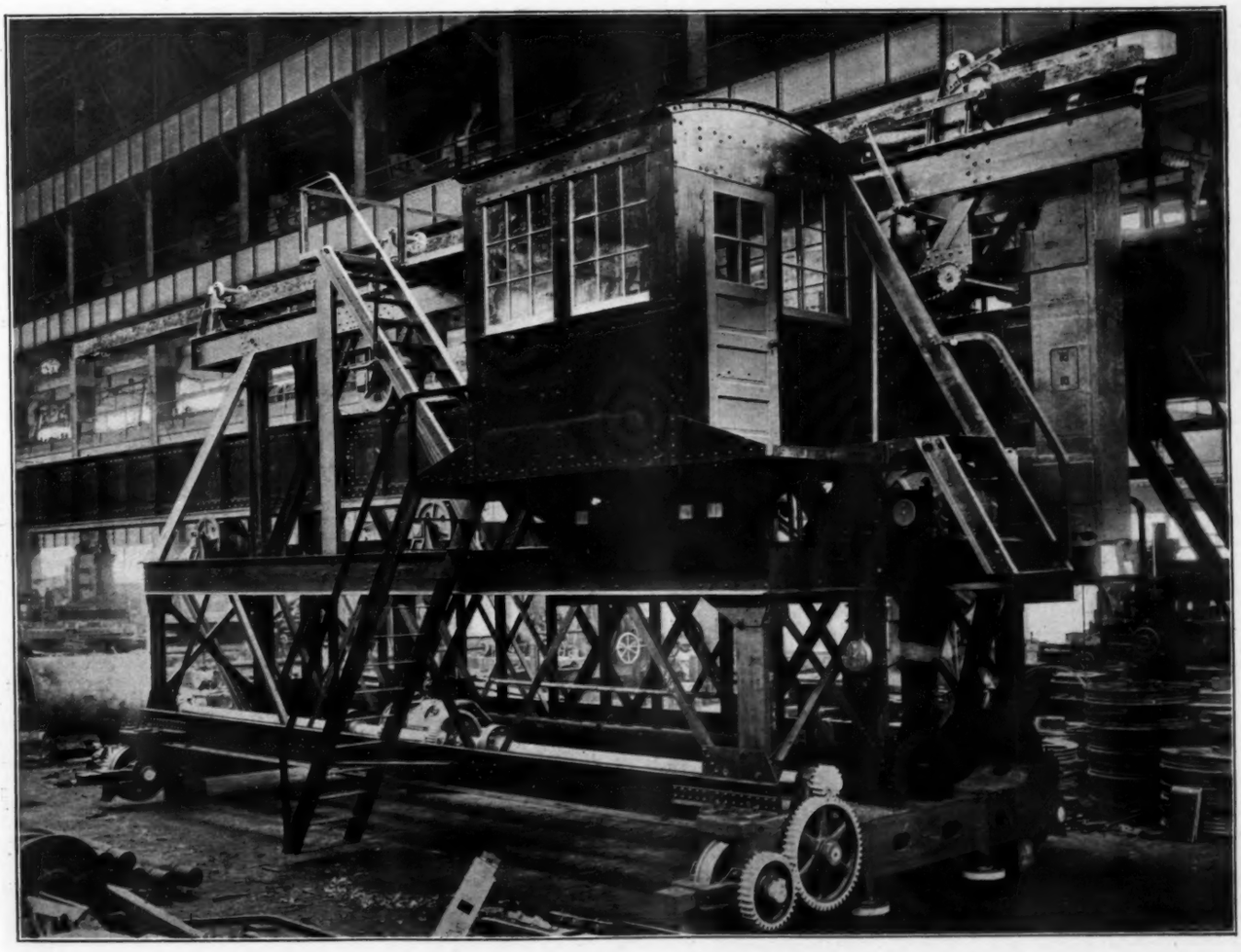


FIG. 4. COKE PUSHER AND COAL LEVELLER FOR USE WITH SEMET-SOLVAY OVENS.

PHOTOMICROGRAPHS OF STEEL AND IRON SECTIONS AT HIGH MAGNIFICATIONS.

(*For Description, see Page* 86.)

FIG. 1.—Photomicrograph taken by Sorby. Blister steel, longitudinal section. Magnification, 9 diameters.

FIG. 2.—1·5 mm. apochromat. Structure of fine lamellar and sorbitic pearlite. Annealed alloy steel—0·84 C., 0·30 Si., 0·45 Mn., 1·12 Cr., 0·12 Ni. As seen under a magnification of 8,000 diameters; actual magnification, 4,000 diameters.

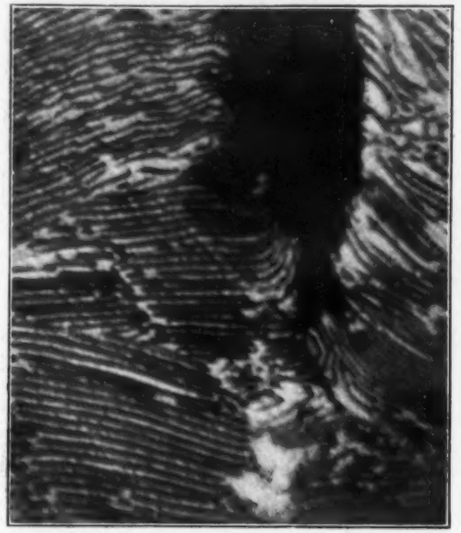


FIG. 3.—Structure of pearlite and graphite. Grey cast iron—3·5 C., 2·5 graphite, 2·82 Si., 0.115 S., 0·28 P., 0·34 Mn. As seen under a magnification of 5,000 diameters; actual magnification, 3500 diameters.

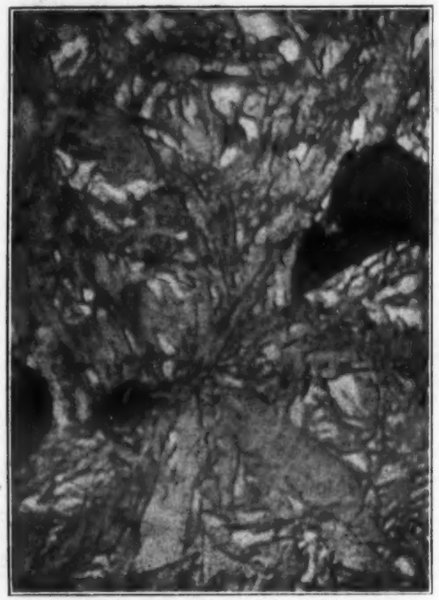


FIG. 4.—1·5 mm. apochromat. Martensite and troostite. Quenched carbon steel—0·90 C., 0·27 Si., 0·29 Mn. As seen under a magnification of 8,000 diameters; actual magnification, 4,000 diams.

FIG. 5.—1·5 mm. apochromat. Pearlite and cementite. Annealed steel—1·41 C., 0.38 Mn. As seen under a magnification of 5,000 diameters; actual magnification, 2,500 diameters.

FIG. 6.—1·5 mm. apochromat Troostite and cementite. Quenched and tempered steel—1·41 C., 0.38 Mn. As seen under a magnification of 5,000 diameters; actual magnification, 2,500 diameters.

(*To face page* 79.)

railwaymen were stated in our article on page 51 *ante*. It is understood that the delegates demand the abolition of the sliding-scale principle; back pay to August 18, 1919; and the standard wage to be based on the highest rate for each grade, plus the 33*s.* war bonus. Sir Eric Geddes, the Minister of Transport, and Sir Robert Horne, the Minister of Labour, went to Paris on Sunday in order to discuss the situation with the Prime Minister. They returned to London on Monday evening. A meeting was held last Wednesday between the Minister of Labour, the Minister of Transport, and the railwaymen's representatives, but no decision was arrived at. Yesterday a conference of delegates of the National Union of Railwaymen was held; it lasted two hours, and at the close Mr. J. H. Thomas, M.P., announced that "the conference had decided by a very narrow majority to accept the settlement on the further explanations of the Government." Mr. Thomas and the Negotiating Committee subsequently visited the Ministry of Transport to notify the acceptance of the terms. We shall give further particulars on the settlement in our next issue.

The Amalgamated Union of Shipbuilding, Engineering and Constructional Workers, with the Boilermakers and Iron Shipbuilders' Society, the Shipconstructors and Shipwrights' Association, and the Associated Blacksmiths and Ironworkers' Society, have drafted a Bill on the 44-hour week for introduction in Parliament at the forthcoming session. Among its clauses, the following may be mentioned:—No person shall be employed for a period of more than 44 hours during one consecutive week (the period between midnight on Saturday night and midnight on the succeeding Saturday night), nor for a period of more than 8 hours during any one day. In addition to the period of employment allowed by this clause, whether such period be 44 hours a week or less, a person may, in case of breakdown or emergency, be employed for a longer number of hours—overtime—in any day; but overtime shall only be worked in accordance with an agreement arrived at between the employer and a trade union, or trade unions, representing the workers concerned. Further, in computing the overtime worked on any day, the hours worked on any other day shall not be taken into account. The penalty in respect of each offence is a fine not exceeding 20*l.*, and a fine not exceeding 5*l.* for each day on which the offence is continued after conviction. Proceedings against an employer may be instituted by or on behalf of a trade union, and any party to such proceedings may appear by an officer of a trade union to which he belongs.

THE PRICKLY PEAR IN AUSTRALIA.—The prickly pear pest has become acute in Australia during the war. The prickly pear plants are cactus, mostly *opuntia inermis*, which indigenous in America were introduced, purposely or accidentally, into Australia, where they have become a very serious nuisance. They kill all other growth and are hardly to be eradicated by mechanical means. Arsenic poisoning has proved the most effective remedy; but the arsenic, the pentoxide or chloride, should not merely be sprayed upon the plants, but injected so as to destroy the roots. Sodium arsenite mixed with caustic soda and common salt is less expensive and also less dangerous a poison, but also less effective than the arsenic compounds alone. Even the spraying is a problem for the engineer as well as for the farmer, and during the war arsenic was not obtainable. According to Bulletin 12 of the Institute of Science and Industry of Australia, 1919, arsenic chloride is now manufactured in Melbourne, and the Queensland Government is going to supply arsenic pentoxide. The cost of eradication mostly exceeds 50*s.* per acre, so that the treatment will scarcely answer for poor scrub. Fortunately the prickly pear is not quite without utility. It can at any rate serve as reserve food for cattle in dry seasons, though the cattle cannot subsist on the cactus alone. Buried 18 in. under the ground it may answer as manure, but that is risky. The fruits and even the succulent leaves or stems yield some alcohol, as has been demonstrated in Spain and Sicily; but the yield is too poor. For paper-making the fibres are short and of inferior felting quality. The ashes of the pear, which make up about 10 per cent. of the dry weight, contain half the r weight of potash. If that potash could be obtained fairly pure without soil contamination, the potash extraction might prove profitable. But the difficulty in most of these possible utilisations lies in the collection and transport of the material; a wagon load of prickly pear is hardly worth troubling about. As the *opuntia* have already conquered 22,000,000 acres in Queensland and New South Wales, and are spreading at the rate of 1,000,000 acres per year, the Advisory Council of the Ministry of Agriculture recommend the establishment of a central laboratory and of two subsidiary laboratories for studying war against the prickly pear mainly by means of insects and fungi. The cochineal insect has almost exterminated the tree pear (*opuntia monacantha*) in Ceylon and India; but this insect is relatively harmless, and experiments made so far indicate that the insects do not attack the prickly pear proper.

YEAR BOOKS AND ANNUALS.

The Colliery Manager's Pocket Book, 1920.—This pocket book for the current year forms the fifty-first annual edition. It is edited by Mr. J. Vincent Elsden, D.Sc.(London), F.G.S., and Mr. Hubert Greenwell, F.S.S., Assoc.M.Inst.M.E., and is published by the *Colliery Guardian*, 30 and 31, Furnival-street, Holborn, E.C. 4, at the price of 3*s.*, bound in cloth. It opens with a diary section and has close upon 400 pages of information on every mining subject; statistics of coal output for over thirty years, of persons employed and minerals raised, of accidents, of safety lamps, coal-cutters; also figures concerning coke, briquettes, &c. These particulars, together with a series of very complete notes which it gives on mining work in its different phases, on coal, &c., will interest not only colliery managers, but also a wide circle of readers and writers for reference purposes.

The Electrical Engineer's Diary, 1920.—This diary for the current year, the twelfth year of publication, edited by Mr. J. H. Johnson, M.I.E.E., Assoc.A.I.E.E., and published at the price of 7*s.* 6*d.* by Messrs. S. Davis and Co., 30 and 31, St. Swithin's Lane, E.C.4, measures as usual 11 in. × 8½ in., and contains about 480 pages of information on all electrical subjects, classified in sections. It deals with the generation of electricity and the machinery for this, boilers, steam turbines, Diesel and other engines; with the numerous applications of electricity for power purposes and for lighting; the installation of telephones and bells, etc. Two new sections cover electric motor control and the installation and maintenance of cables. The articles are well written, carefully illustrated and contain figures and formulæ which will be greatly appreciated by all electrical engineers. An index is included for the use of consulting engineers, central station engineers and contractors, giving the name and address of manufacturers of articles which are placed on the market with a distinctive name; also a vocabulary of technical terms and definitions; the wiring rules of the Institution of Electrical Engineers; standardisation rules; data on the electricity supply in cities throughout the United Kingdom, &c. The diary portion, four days per page, is at the end of the book.

The British Steel Piling Company's Diary, 1920.—The desk diary issued by this company, whose offices are at Dock House, Billiter-street, E.C. 3, illustrates the company's piling sections and the methods of assembling—it has tables of dimensions and weights, together with calculations and formulæ. It deals also with pile-driving plants. The diary portion has three days per page, this being followed by a number of sheets of squared paper for the use of engineers and contractors.

Almanacks and Calendars.—We have received from Messrs. Charles Churchill and Co., Limited, machine-tool manufacturers, Birmingham, Manchester, &c., and 9 to 15, Leonard-street, Finsbury, E.C. 2, a handsome daily tear-off calendar. A daily tear-off calendar also comes to us from Commercial Cars, Limited, Luton. Messrs. George Cradock and Co., Limited, Wire Rope Works, Wakefield, have sent us one of their clearly-printed almanacks. Other, monthly, calendars received are from Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, 8, Great George-street, Westminster, S.W. 1, illustrating some of their numerous specialities; from Messrs. Edgar Allen and Co., Limited, Imperial Steel Works, Sheffield; from Messrs. Clayton and Co., Huddersfield, Limited, Karrier Works, Huddersfield, illustrating their establishment and their various vehicles; from Messrs. George Fletcher and Co., Ltd., specialists in colliery, mining and cement works plant, Derby; from the Submarine Signal Company, Friars House, New Broad-street, E.C.; from Messrs. George Ellison, mechanical and electrical engineers, Perry Bar, Birmingham and London, Manchester, Leeds, &c. We have also received monthly calendars from the Consolidated Pneumatic Tool Company, Limited, Fraserburgh, Scotland, and London; Messrs. Peckett and Sons, Limited, locomotive builders, Bristol; George Beaufort Richards, R.M.N., King's Hill Chambers, Wednesbury, illustrating the Richards' and Bradley's patent "New Universal" testing machine. At the time of going to press, a weekly tear-off calendar comes to us from Messrs. Ashwell and Nesbit, Limited, engineers and ironfounders, Leicester, Manchester, &c.; a universal calendar from Messrs. S. G. Leach and Co., Limited, 26 to 30, Artillery-lane, London; a writing-pad with diaries and note sheets from Messrs. Johnson and Phillips, Limited, Electrical Works, Charlton, London, S.E. 7; a monthly tear-off almanack from Messrs. Harrison and Sons, Printers, 44 to 47, St. Martin's-lane, W.C. 2; and a pocket diary from Messrs. Edward Wood and Co., Limited, Ocean Iron Works, Ordsal-lane, Manchester.

THE LATE MR. ALEXANDER IZAT.

WE regret to have to announce the death, which occurred at his residence, on the 2nd inst., in his seventy-sixth year, of Mr. Alexander Izat, C.I.E., M.Inst.C.E.

Mr. Izat joined the Indian Public Works Department as a Stanley Engineer in 1863, being posted to the Berars Hyderabad Assigned Districts. In 1870, whilst still in the Berars, he was given an opportunity which decided his future and directed him into railway construction. At that time, the Government of India were intent upon the rapid building of a short branch from the Great Indian Peninsula Railway at Jalamb, to Khangaom, one of the chief cotton marts in the Bombay Presidency, to help the cotton industry. The work was being delayed. Mr. Izat was recommended to the Cotton Commissioner as being able to push the work through, and he was selected. The branch, the first State Railway in India, was completed so rapidly and efficiently that Mr. Izat's reputation as a railway engineer was established and his rapid rise in the profession assured.

From 1870 to 1874, Mr. Izat was an executive engineer on the Nizam's State Railway, where he built the Cogna and other large bridges. He then went to the Holkar State Railway, on which he constructed the Holkar Nerbudda Bridge, having 14 spans of 200 ft. In 1877 and 1878, Mr. Izat was engineer-in-chief of the Dhond Manmad line, and between 1878 and 1880 he built the Bhavnagar Gondal metre-gauge railway; on completion of this he was for a short time employed on the Hubli Gadag section of the Southern Mahratta Railway. Early in 1883, Mr. Izat was appointed the agent and chief engineer of the Bengal and North-Western Railway Company. In the same year, he was appointed consulting engineer to the Rohilkund and Kumaon Railway, and in 1885, on the opening of that railway to Kathgodam, the working of the recently-opened Bareilly Pilibhit Provincial Railway was entrusted to the company, forming the beginning of the present Rohilkund and Kumaon Railway, Mr. Izat being appointed chief engineer. From then until the time of his death, he worked most actively for the promotion and development of these two railway systems and, incidentally, he largely contributed to the growth and expansion of the whole metre-gauge system in Northern India, acting at different times as consulting engineer to other railways. For several years Mr. Izat was on the Legislative Council of the Lieutenant-Governor of the United Provinces. The outstanding example of Mr. Izat's energy was the linking up of the Bengal and North-Western Railway system with the Rohilkund and Kumaon Railway and Rajputana Malwa Railway, and, later, with the Eastern Bengal metre-gauge system, thereby consolidating the metre-gauge throughout the whole of Northern India. All this railway work also involved the construction of numerous railway bridges and stations with which Mr. Izat's name is closely associated.

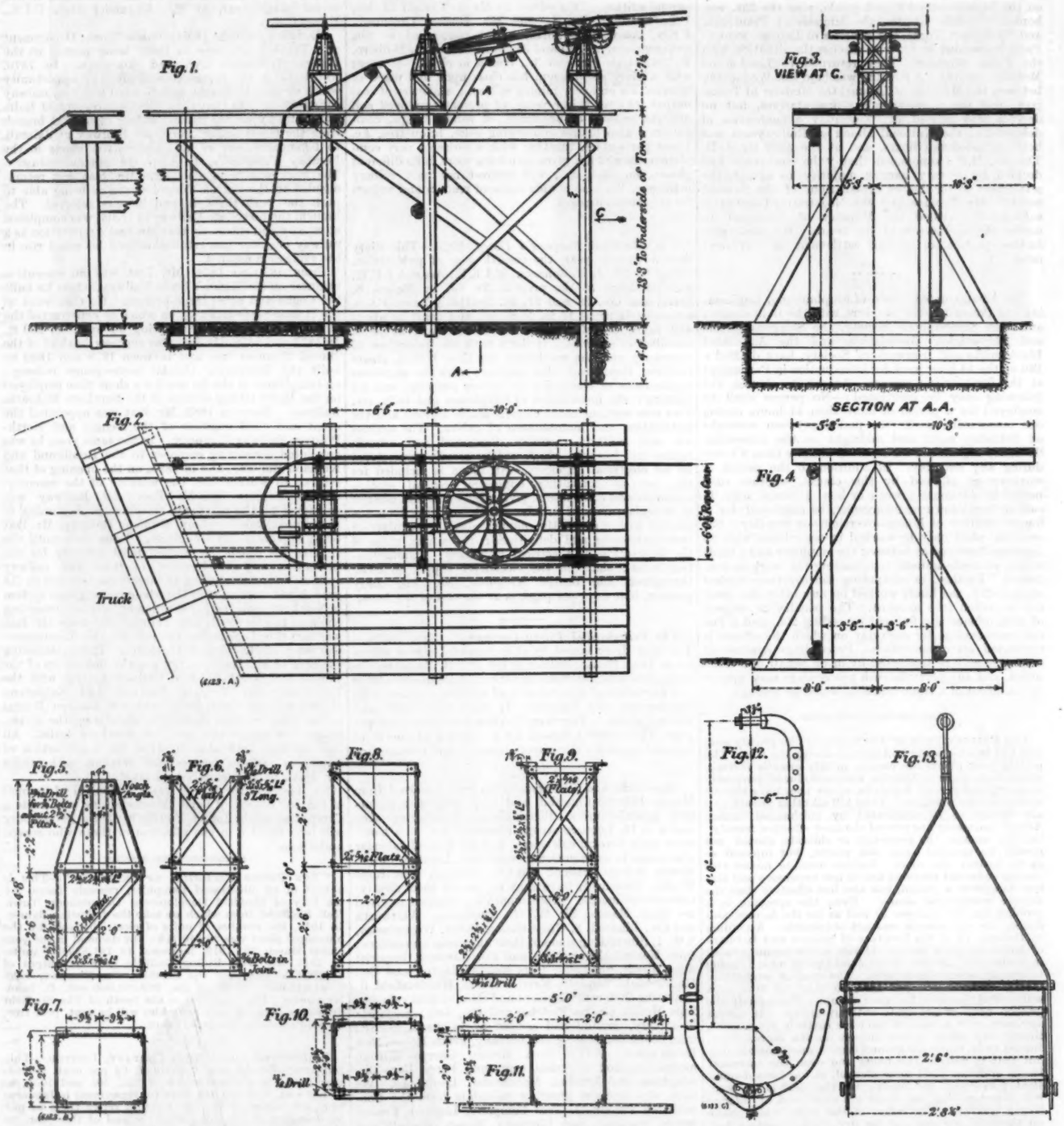
Mr. Izat was for several years a Member of Council of the Institution of Civil Engineers, and was made a Companion of the Indian Empire in 1898; his memory will long survive in the affection of those who served under him.

"THE POWER FACILITIES OF SHEFFIELD."—This is a title of an illustrated pamphlet, recently issued by the City of Sheffield Development Department, Town Hall, Sheffield, from which we take the following figures. In 1914, the number of units of electricity sold by the municipal plant was 26,546,718; the demand in the year ended March 25, 1919, increased to 161,839,041 units. In 1917, the West Riding Coalfield gave an output of 40,872,613 tons, and the Sheffield Gas Company sold 5,841,445,000 cub. ft. of gas, 909,000,000 cub. ft. being for power. The pamphlet is the tenth of The Sheffield Series; a copy of each pamphlet will be sent, post free, on application to the department.

BIRMINGHAM SMALL ARMS COMPANY, LIMITED.—This company offer for sale 2,500,000*l.* 6½ per cent. twelve-year notes, in denominations of 25*l.*, 50*l.* and 100*l.*, at 99 per cent. While the date for repayment is January, 1932, the company has the right to repay them at par by drawings at any time after the end of this year, on giving three months' notice in writing. As is well known, this company now owns the whole of the share capital of the Daimler Company and Messrs. Burton, Griffiths and Co., and 99 per cent. of the share capital of Messrs. William Jessop and Sons, Limited, the value of the net assets on all the companies embraced in the combination being 5,458,257*l.* The net annual profits of the company is also certified by the chairman, Sir Hallewell Rogers, M.P., for the last seven financial years, after providing for excess profits duty and ordinary depreciation, and making allowance for the variation of the dates on which the financial years of the several companies end. The figures approximately are as follows: 1913, 365,699*l.*; 1914, 361,782*l.*; 1915, 623,725*l.*; 1916, 838,193*l.*; 1917, 1,417,395*l.*; 1918, 1,449,356*l.*; 1919, 1,281,228*l.*—total, 6,337,378*l.* The application for these notes is to be made to the Imperial and Foreign Corporation, Limited, 1, Broad-street-place, London, E.C.

(To face page 79)

SEMI-PORTABLE AERIAL ROPEWAY.



THE question of transporting some definite quantity of a particular material of a non-recurrent character has often to be considered by engineers and contractors. It necessarily leads to a nice balancing of costs between many possible systems. One system may offer inexpensive haulage only after large initial outlay, while in another the actual working costs may be high though the initial outlay small. In such circumstances any appreciable reduction of installation costs of a system promising low working expenses is of interest. An example of work in this direction is to be found in a type of aerial ropeway which we illustrate in Figs. 1 to 20, on this and the next pages. This ropeway was designed by the Aerial Ropeway Transporters, Limited, of Craven House, Kingsway, London, W.C. 2, for Messrs. William Muirhead MacDonald Wilson and Co., Limited, railway and public works contractors, of 41, Parliament-street, Westminster, S.W. 1, and was erected to handle timber on an estate in Devonshire, between Halwill Junction and Launceston, on the London and South-Western Railway.

The plantations were less than a mile from the railway, but the distance to the nearest loading siding, over bad road, was more than three miles. Further, the only available loading point was already congested with local traffic; to the high cost of road transport and re-handling would therefore have been added considerable delay. For such work an aerial ropeway was seen to be pre-eminently suited, both on account of the ease of erection, and of obtaining wayleaves across land, and low running costs.

The main objection to permanent installations on concrete foundations for handling limited quantities of material is the high cost and the length of time required for the erection of a plant which, after it has served its immediate purpose, could not be of further use except at renewed heavy expenditure. It was with this in view that the semi-portable type of terminals which we illustrate, were designed. The intermediate towers are simple structures, comparatively roughly constructed. The chief interest centres in the terminals. The ropeway is of the single-cable type, with the driving and tension gear at the upper or loading end. At the lower, or unloading end, there is an anchored free sheave only. This was sited on a short siding put in on the London and South-Western Railway main line. The design embodies standard parts composing the towers and fittings, while all concrete work is obviated by

SEMI-PORTABLE AERIAL ROPEWAY.

Fig.14.

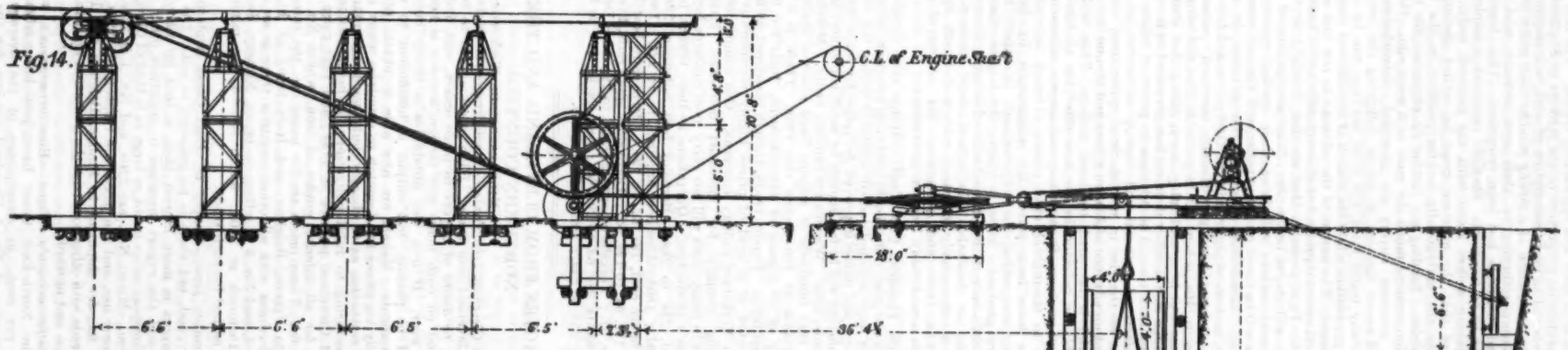
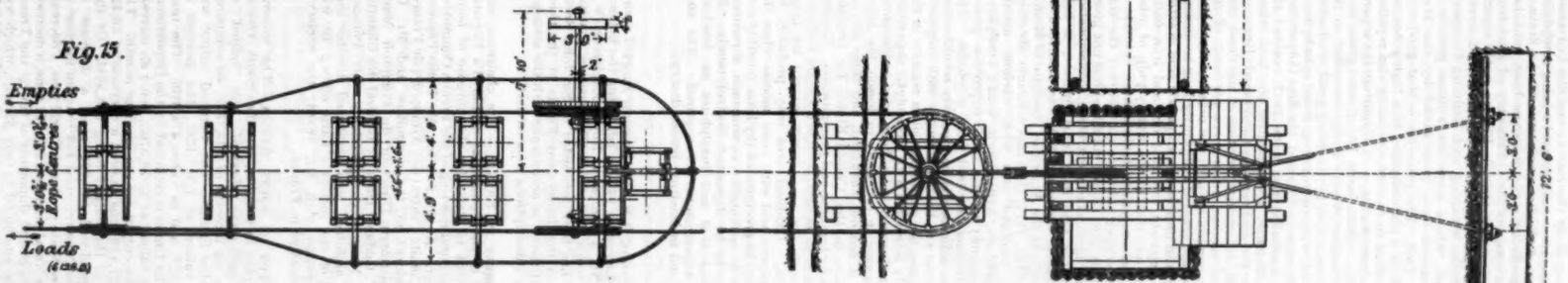


Fig.15.



use of timber cribbing, &c. The unrealisable expenditure incurred was small.

At both the upper and lower ends the terminal shunt rail is carried by transomes supported by standard towers, Figs. 1 to 11, and 14 and 15. These towers are composed of one or more rectangular units of framing of four legs supporting a top unit, of which the lower half is also rectangular. The upper half of the top unit, Figs. 5, 6 and 7, forms vertical guides for short angle irons carrying the transom. These angles can be adjusted and bolted at intervals of 2 in. over a considerable height, so that any irregularities of the ground level can be compensated. The transom is clamped to the adjustable angles, not bolted, so that lateral adjustment may be secured as well as vertical. In this way large inequalities of ground surface can be taken care of without difficulty, thus obviating heavy excavation on bad sites. Figs. 8 to 11 illustrate the lower standard units, which are shown in use in Figs. 14 and 15.

The driving and loading terminal also embodies the tension gear, as shown in Figs. 14 and 15, on this page. The cable is spaced 6 ft. ¼ in. centre to centre, and the return sheaves at both ends are of a corresponding diameter. The rope is led over deflection pulleys carried by a standard tower, down to the underside of the driving pulleys arranged on a shaft carried near the base of a group of three standard towers. From the driving pulleys the rope runs back to the tension

Fig.16.

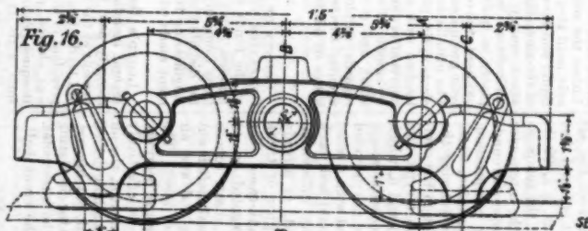


Fig.17.

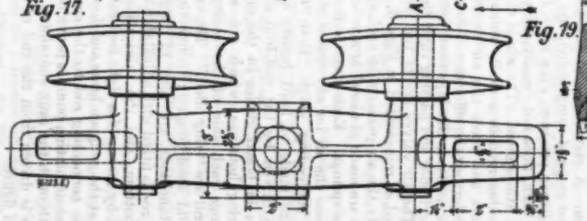


Fig.18.

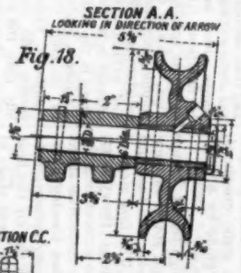
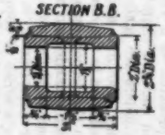


Fig.19.

Fig.20.



sheave which is arranged on wooden slides, a pull being exerted by tackle, of which one end is attached to a weight suspended in a timber-lined pit, while the other is fastened to a hand winch anchored to the ground some distance back. The unloading terminal consists of a rough timber structure shown in Figs. 1 to 4, on page 80. This has a platform 13 ft. 3 in. above the ground level, on which standard-top tower units are arranged for the guide pulleys and shunt rail. The rope at this end is deflected from the horizontal down to the free sheave just behind the deflection pulleys. This sheave is anchored to a cable carried to the bottom of a rough timber crib box underneath, and forming part of the structure of the platform. It will be evident that at this end also the actual fixing of the towers could be comparatively rough, and final adjustment of the transom carried out to suit the proper alignment. This platform is provided with a ramp running down to the truck side.

In both terminals the shunt rail is held in place by jaws on the transomes, which grip it and allow of a further small vertical adjustment of the rail itself, so that true alignment may be secured. The arrangement thus allows for a rough vertical adjustment of the transom at the towers, and a further fine adjustment at these rail jaws, while horizontal alignment is provided for in the clamping of the transom. It will thus be realised that no great refinement in the setting of the towers is essential. The details of the timber structure work are clear from the figures. Practically the whole of it can be salved when operations are completed, so that the money sunk in permanent structures is very small.

The length of the particular ropeway described is 4,765 ft. There are 20 intermediate towers. The capacity of pit props is 10 tons per hour in individual loads of 10 cwt. The speed of the rope is 350 ft. per minute, and 18 carriers are employed, being

despatched at intervals averaging 2½ minutes. The cost for labour and running expenses works out at about 6d. per ton.

The type of carrier used is shown in Figs. 12 and 13. It is furnished with a tipping cradle. The trolley and grips are shown in Figs. 16 to 20. The grips are not pivoted but are held by pins in the trolley head, and work on rocker points on the head casting. This type of semi-portable ropeway installation is designed for dealing with quantities of up to 5,000 tons.

FOUR-STAGE AIR COMPRESSOR.

On page 84 we illustrate a single-crank four-stage air compressor constructed by Messrs. Siebe Gorman and Co., Limited, of 187, Westminster Bridge-road, and intended to supply 35 cub. ft. of "free" air at a discharge pressure of from 2,400 lb. per square inch, when running at 400 r.p.m. As will be seen from the general view, Fig. 1, the compressor is compact in form, and although the crank is enclosed, there is ready access to glands and other parts that may require occasional attention. Details of the design are illustrated in Figs. 2 to 6. One object aimed at has been to reduce the number of separate working parts to a minimum. Thus, although there are four stages, but two cylinders are employed, and these have plungers rigidly connected to one and the same crosshead, which is reciprocated in a vertical guide by a crank rotating in an enclosed chamber below.

The air cylinders are made of high-tensile bronze in one casting. The first and second stages of compression are effected in the one cylinder, and the third and fourth in the second cylinder. The first stage of the compression is carried out at the top of the cylinder, and the second in the annular space surrounding the trunk. After compression in each successive stage, the air enters a series of copper tubes forming intercoolers, the surface of the tubes being proportionate for each stage so as to extract from the air the heat of compression before it passes to the next stage of compression. A cooler is also fitted to cool the air after the last stage of compression, and it is found that its final delivery pressure, even when this is 3,000 lb. per square inch, does not greatly exceed the temperature of the atmosphere. The whole of the intercooler tubes are submerged in a tank, which also surrounds the cylinders and cools the air during compression. To increase further the efficiency of compression, water injection is utilised, the injection water entering the first-stage cylinder and passing right through the compressor. The air valves are of the poppet type, and are arranged as represented in Figs. 4, 5 and 6, which show clearly the air passages to each successive stage. The valves are made of nickel bronze and are provided with bronze springs. Each stage is fitted with a relief valve, in case the air for any reason should leak back from the succeeding stage. Both the differential plungers are made of hard bronze and, as already stated, are driven by the cast-iron slipper or trunk which runs in bored guides in the crank-case. The main bearing housings, which are spigoted on to bored facings each side of the casing, have bronze bearings, and are "ring oiled." The crankshaft is cut from a solid steel forging; connecting rod and air cylinder stanchions are also of forged steel. The connecting rod is fitted with adjustable bronze bearings top and bottom, and the lubrication is effectively carried out by means of a sight-feed lubricator, the oil running in at the gudgeon brass and down a hole drilled through the connecting rod to the crank-pin brasses. A gun-metal circulating pump is provided for circulating the water through the tank containing the intercooler. This pump is driven from the end of the crankshaft, as shown in figure.

After the final compression the air is delivered to a long tube which serves as a separator, and removes from the air any oil or water suspended therein, as the result of its passage through the compressing cylinders. This is accomplished by diverting the incoming air and water against the side of the tube by means of suitable baffles and collecting the water thus separated, at the bottom of the tube, where a drain valve is fitted. The air passes away at the top of the tube.

Contracts.—Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, are at the present time building locomotives of various types for the United Kingdom, India, Nigeria, Trinidad, Belgium, Argentina, Brazil and Java.

Personal.—The British Steel and Iron Exporters, Limited, a private limited company, having offices at 22 and 23, Laurence Pountney-lane, E.C. 4, announce that they were registered on October 25, at Somerset House, with a capital of 50,000*l.*, for dealing in steel, iron and machinery.—The Scientific Instrument, Glassware and Potash Production Section of the Board of Trade was transferred on Wednesday last, the 14th inst., from 7, Seamore-place, W., to the main offices at Great George-street, S.W.1. The telephone number is Victoria 9800 and the telegraphic address "Indumandep, Parl, London."

ZINC FROM LOW GRADE ORES.

In Bulletin 157 of the United States Bureau of Mines, on "Innovations in the Metallurgy of Lead," Dorsey A. Lyon and Oliver C. Ralston gave an account of experimental researches, conducted by the Bureau and the University of Utah, in co-operation with several mining companies, on the utilisation of the low-grade ores of the State of Utah.* A further Bulletin 168 has since been published by the same authors, on the "Recovery of Zinc from Low-Grade and Complex Ores." Electro-static separators, we note, though not perfect, have done good service in the United States Smelting and Refining Company, of Midvale, Utah, where some six million pounds of zinc formerly wasted have been saved by the Huff separators since 1909. The principle is that good conductors, dropped on a plate charged to a high potential, are at once electrified to the same polarity and repelled, whilst poorer conductors adhere. To facilitate the separation, the particles—which must be of sand-grain size, not dusty—are themselves previously electrified to the opposite sign. Galena and pyrite being good conductors are thus separated without roasting, from sphalerite, a bad conductor. As regards flotation, the Zinc Corporation of Broken Hill (Australia) has, since 1913, roasted the zinc-lead ores sufficiently to sulphatise the lead which then floats, whilst the zinc remains submerged (Horwood process). In Utah, differential flotation of zinc-lead ores has been a partial success, 10 or more per cent. of the one metal always remaining with the other. Mixed zinc and iron sulphides are roasted sufficiently long to destroy the surface of the iron pyrites and sulphuric acid is afterwards added to separate the zinc ore and iron oxide by flotation. The addition to the watery pulp of other oxidising agents, permanganate, bichromates, chloride of lime, and also of copper sulphate (to convert the zinc sulphide superficially into copper sulphide) has not given satisfaction. The "igneous concentration," volatilisation and oxidation of the zinc in a blast furnace, is best effected in a Wetherill furnace, which was described by Stone in the Bulletin of the American Institute of Mining Engineers, September, 1917. The zinc solutions obtained by leaching the oxidised ores with various agents (sulphuric, hydrochloric, hydrofluoric acids, bisulphite, caustic soda, ammonia) contain more impurities generally than the solutions prepared from sulphides. The silicic acid in these solutions is particularly troublesome. Unless the solutions are heated strongly with sulphuric acid until they fume, the gelatinous silica remains in the liquid and severely interferes with electrolytic deposition of the zinc. Hydrofluoric acid has been tried as bleaching agent mainly because it promised to lessen the silica difficulties; but it has not answered, and there are no plants in operation in the United States for treating oxidised zinc ores by leaching and precipitation. Electrolytic precipitation is to be dealt with in a special Bulletin. The installation costs are very heavy, except for large electrolytic plants. Oxidised ores may probably be leached with sulphuric acid with more success when the zinc is afterwards to be precipitated (by lime, possibly also by caustic alkalis or carbonates, or ammonia, if recoverable), and is not to be deposited electrolytically. As regards sulphurous acid and bisulphites as leaching agents, further experiments are required. The zinc losses in mining and in smelting remain heavy.

County of London R.E. (V.) London Army Troops Companies.—A cheque for 94*l.* 8*s.* 5*d.*, being the balance of the funds of No. 3 Company, Royal Engineers (V.), London Army Troops Companies (Engineering Institutions Company), has been forwarded to Sir John Snell, for distribution to the Benevolent Funds of the three Engineering Institutions, in accordance with the arrangement made when subscriptions were invited.

Lloyd's Registry in France.—The chairman and several members of the Committee of Lloyd's Register recently paid a visit to Paris for the purpose of being present at the inaugural meeting of the French Committee of Lloyd's Register. At this meeting, Mr. Denis Pérouse, president of the Comité Central des Armateurs de France, was elected president of the committee and Mr. U. Bocquet, Administrateur-Directeur du Comptoir Maritime, with Mr. F. Godard, Director Général des Chantier et Heliers de St. Nazaire, vice-presidents. Mr. Poincet, a French naval architect, was appointed director and Ingenieur-conseil of the society's Paris office; he will work in collaboration with Mr. Ward, the society's technical representative in France.

Mineral Output of South Africa.—The mineral output for the Union in October, says *The South African Mining and Engineering Journal*, was valued at 4,892,928*l.*, being an increase of 569,782*l.*, as compared with the September figures. The diamond output was 264,814 carats, valued at 1,547,138*l.*, the increase in carats being 37,527, and in value 474,910*l.* The total gold output for the Union is returned by the Department of Mines as being valued at 3,078,576*l.*, being an increase of 106,965*l.* on the output for the previous month. The coal output of 921,438 tons showed a decrease of 26,426 tons, the value of the output being 314,568*l.* Of this the Transvaal produced 590,922 tons, a decrease of 14,500 tons. The Cape returned 403 tons, an increase of 46 tons. The Free State produced 67,022 tons, a decrease of 878 tons, while Natal produced 263,091 tons, a decrease of 1,094 tons. Sales and shipments of tin by the Transvaal and the Cape amounted to only 52 tons, which was assessed at 10,368*l.* Labour returns show that 36,072 whites and 256,856 natives were engaged in mining in October, the former figure being an increase of 15, and the latter a decrease of 1,759 on the September figures.

* See Engineering, vol. cviii, page 284.

NOTES FROM SOUTH YORKSHIRE.

[From our own Correspondent.]

Sheffield, Wednesday.

Iron and Steel.—Failure to arrive at a settlement of the moulders' dispute has caused keen disappointment in the local steel and engineering trades. The fact that a considerable proportion of the strikers in Sheffield are in favour of an early resumption of work, was responsible for the circulation of a strong rumour that many of the men were returning on their own account, and that several foundries had been re-opened. This, however, proves to be incorrect. Sheffield engineering employers are taking a firm stand with the national body, and declare that the question must be settled nationally, despite the undoubtedly serious position in the local industries. Pending any further development, the trade position remains much the same as a week ago. Orders from overseas buyers are plentiful, notwithstanding an all-round increase in prices, following the revision of railway traffic rates, but little headway can be made with production while the dearth of moulds and castings continues. The extent of the advance in raw and semi-finished material prices, has in many cases yet to be determined. It is probable that another fortnight or three weeks will elapse before the official associations of iron and steel makers will issue their revised quotations. These will be based on the experience of the past month's trading. Meanwhile, following the advance in coke prices, makers of pig-iron in the Derbyshire and Lincolnshire districts have provisionally increased quotations 7*s.* 6*d.* to 10*s.* a ton. It is probable that the ultimate increase will be considerably more, seeing that foundry and forge iron in other districts has advanced as much as 15*s.* to 1*l.* a ton. The advance in prices of billets and manufactured material will depend, of course, on the extent of the rise in raw material quotations, but at present an advance of 35*s.* on billets and 50*s.* on sectional material is favoured by local makers. This will inevitably be reflected in the new rates for all kinds of finished products, from railway and marine requirements down to the lighter steel goods. Though substantial orders have been placed for rolling-stock by British railway companies, the improvement in export trade is very gradual. India is taking the largest share of Sheffield's output, but little business is being done with Canada or Australia. Galvanised sheet makers are doing a substantially increased trade with South Africa, Australia, India and Argentina. The output of mild steel is considerably below requirements.

South Yorkshire Coal Trade.—House coal merchants experience great difficulty in obtaining adequate supplies. Orders have accumulated considerably during the recent holidays, and unless improved deliveries are forthcoming, the shortage will be felt acutely by small consumers in the Yorkshire area. Wagons are running badly. Merchants state that hundreds of wagons have not yet made an appearance at the depots this year. There is a fair supply of all classes of manufacturing fuels for home requirements. Export trade, though restricted, is being conducted at a level of prices highly remunerative to South Yorkshire colliery concerns. Gas companies are pressing strongly for increased deliveries. Existing stocks in many cases will not carry local concerns beyond a week's production. Quotations:—Best branch handpicked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.*; Derbyshire best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; best slacks, 24*s.* to 25*s.*; nutty, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

[From our own Correspondent.]

Middlesbrough, Wednesday.

The Cleveland Iron Trade.—Great firmness characterises the Cleveland iron trade. High prices appear to be no check to desire of buyers to place orders, and, indeed, demand on both home and foreign account is heavier than ever. If iron was obtainable a heavy business would be passing, but output is insufficient to meet requirements. Makers are now able to obtain phenomenally big prices for despatch to countries where there is no restriction as to charges, but they are honourably endeavouring to fulfil obligations to home customers. No. 3 Cleveland pig-iron is 175*s.*, and that price also rules for all inferior grades of iron, whilst No. 1 is 182*s.* 6*d.* These prices are for home use, the rates for sale to France, Belgium, and Italy being 5*s.* higher. For business with all other countries there is an open market, and No. 3 is selling to Japan, Norway, Sweden and Denmark at 210*s.*, which is now the minimum price named for such trade.

Hematite Iron.—Supply of East Coast hematite is fairly good, but there is no pressure to sell. The area for export is more limited than is that for Cleveland iron, and the export premium to countries other than our European allies is not so large as is that of Cleveland pig-iron. Mixed Nos. are 220*s.* and No. 1 is 222*s.* 6*d.* for home use, and the prices are respectively 225*s.* and 227*s.* 6*d.*, for shipment to France, Belgium and Italy. For trade with other countries the quotation for hematite is 230*s.* and upward.

Blastfurnacemen's Wages.—Blastfurnacemen's wages on the North-East Coast have just been advanced 2·75 per cent., in consequence of the average net selling price of No. 3 Cleveland pig-iron for the last quarter of 1919 having been certified at 161*s.* 2·34*d.*, as compared with 158*s.* 4·98*d.* for the previous three months. This brings wages from 104·25 per cent. to 107 per cent. above the recently raised standard.

Foreign Ore.—Foreign ore is very stiff. There are reports here that Germany has been buying rubio

extensively, and some sellers now quote on the basis of 48*s.* on a 17*s.* parity freight, so that with charterings, Bilbao-Middlesbrough, at 30*s.*, rubio, of 50 per cent. quality, advances to the neighbourhood of 61*s.* c.i.f. Tees.

Coke.—Coke keeps strong, and scarce. Medium blast-furnace kind is 50*s.* 3*d.* at the ovens, and quality low in phosphorus is 53*s.* at the ovens.

Manufactured Iron and Steel.—Finished iron and steel producers are exceedingly busy, and are not bothering about new business. Buyers are quite prepared to follow the all-round 25*s.* rise in steel, but they experience great difficulty in placing orders. Common iron bars are 23*l.*; marked bars, 25*l.*; small steel bars, 22*l.*; steel ship, bridge and tank plates, 20*l*; steel boiler plates, 23*l.*; steel angles, 19*l.* 10*s.*; steel joists, 19*l.* 10*s.*; and heavy sections of steel rails, 18*l.* 15*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—With business once again in full swing, the Scotch steelmakers are being faced with the trouble of the past year—the difficult matter of supplying the huge quantity of steel material demanded by consumers. The output during the past week has been very good, but it is far from equal to what is wanted, and managements have just to be content with trying to make what is available go round. It is hoped that by good constant work the requirements will ultimately be met, but it will be many months before such a state is possible, as orders already on hand can hardly be completed for some considerable time. New business is being offered daily, and about the only question asked is the probable date of delivery. In the case of ship plates alone the quantity required by Clyde yards is indeed enormous, and there exists a steady pressure for deliveries. Shipbuilders have so much work to do that the weekly consumption of steel is on a very large scale, and much anxiety prevails at times as to the prospect of the supply of plates being sufficient to keep them running. On the other hand, the producers are endeavouring to the best of their ability to keep all customers supplied. The demand for sections is also very good, and in the case of black sheets, while the output is large, the demand, for the heavier gauges in particular, is still far ahead of the supply, and it will take months to work off the orders on hand. There is not so much doing in galvanised sheets, but for many purposes the present price is much too high, although it is recognised that lower quotations cannot be expected meantime. The export trade is very small at present owing to home requirements, with the result that many inquiries cannot be looked at. In consequence of the increases in railway rates and higher prices of raw material, all steel quotations have been raised as from to-morrow, January 15, but even these advanced prices are not likely to affect buying. The present position of the industry was very carefully considered at a meeting of the Scottish steelmakers yesterday, and it was finally agreed to add 25*s.* per ton to the price of ship plates and sections, and 30*s.* per ton to boiler plates, while black sheets are up by 40*s.* per ton. The current quotations, f.o.r. at makers' works, are now as follow, for home consumption:—Ship plates, ¼ in. and up, 21*l.* per ton; under ¼ in., down to and including $\frac{1}{16}$ in., 25*l.* 5*s.* per ton; under $\frac{1}{16}$ in., down to and including ⅛ in., 26*l.* 15*s.* per ton; angles, &c., 20*l.* 10*s.* per ton; boiler plates, 25*l.* 10*s.* per ton; black steel sheets, 28*l.* per ton, as the basis for ¼ in. How long these quotations may hold good is very doubtful, and some argue that another advance will be inevitable in the near future.

Malleable Iron Trade.—No change has taken place in the malleable bar iron trade of the West of Scotland, and makers are being hard put to it to supply even a part of what is demanded. Output is still behind, and that alone is the cause of much anxiety on the part of producers. Inquiries continue good, particularly from abroad, but many very tempting lots have reluctantly to be turned down, as there is no prospect of reasonable delivery. Prices are very firm and tending higher.

Scotch Pig-Iron Trade.—A strong tone prevails in the pig-iron trade of Scotland, but makers are faced with a shortage of ore owing to the scarcity of tramp steamers usually carrying this traffic. An increase in the supply of ore would be most welcome, as the condition at present is causing some anxiety to makers as the demand for pig-iron is heavy. Quotations have gone stronger again, and further rises are expected daily. Foundry iron is called 11*l.* 5*s.* for No. 1, and from 11*l.* to 11*l.* 10*s.* per ton for No. 3. Hematite is in good demand at firm quotations.

Shipbuilding.—Quite a number of changes have taken place in recent times in some of the shipbuilding concerns on the Clyde, and Amalgamated Industrials, Limited, London, have now secured the control of three of the Port Glasgow yards. The three firms taken over by the London company are, the Clyde Shipbuilding and Engineering Company, Limited; Messrs. Murdoch and Murray, Limited; and Messrs. Ferguson Brothers, Limited. Several changes have been made in the directorate of the different companies, but each will be carried on under its old firm name, and little or no change will meantime be made in the class of work in which each firm specialises.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Coal Market.—Very little business has been arranged on the coal market during the past week. Prices have remained at record levels, though to-day the undertone showed an irregular tendency, due to the fact that the recent stormy weather has retarded the movement of shipping and dislocated previous arrangements. In consequence, collieries, though fully stemmed, have been uncomfortably placed in respect to empty wagons and, in order to secure a quick return of trucks, have been disposed to sell small isolated parcels at slightly lower prices to buyers able to take immediate delivery. For next week's loading, too, there appeared to be rather more coal for disposal, though prices have not undergone any appreciable alteration, as sellers indicated 110*s.* for the best quality Admiralty large and from 105*s.* to 107*s.* 6*d.* for the leading Monmouthshire and dry large, with ordinary qualities from 100*s.* Buyers attached some significance to the fact that collieries producing the best quality coals were not asking more than 110*s.*, whereas a week ago, in isolated cases, they talked about 120*s.* Smalls have been very scarce and have touched 95*s.* for best steams, but to-day the tone was slightly easier and prices range from 90*s.*, with ordinaries from 85*s.* and inferiors from 75*s.* In the bituminous section, No. 2 Rhondda large was firm from 95*s.* and throughs 85*s.* Coke was very scarce at 120*s.*, and patent fuel was nominally worth 110*s.*, with supplies extremely scarce. There has been a sharp increase in the price of imported pitwood up to 80*s.* having been realised, compared with 70*s.* a week ago. The inland demand continued heavy, and large quantities have been allocated for home consumption and despatch to Liverpool, &c., by sea and rail for bunkering purposes. Coal exports last week totalled 272,663 tons, of which 144,681 tons went from Cardiff, 63,250 tons from Newport, 45,404 tons from Swansea, and 18,728 tons from Port Talbot.

The Iron and Steel Trades.—Generally there is no change in conditions. The demand for all commodities, on the whole, is in excess of available supplies, and in the majority of cases makers are booked up with orders over the first half of the year, and in some instances till September. This is especially the case in respect to tin plates, which range from 58*s.* to 60*s.* for the basis box. The export inquiry is active, and 108*s.* 6*d.* is reported to have been paid for F.C.B.Y.'s for March shipment. Tin and sheet bars are firm at 18*l.* per ton, and in view of the increased cost of production and advanced railway rates are expected to reach 20*l.* Galvanised sheets are firm at 47*l.* 10*s.* for 24-gauge corrugated, in bundles, with other gauges from 57*l.* to 60*l.*

THREE-CYLINDER 0-8-0 TYPE SUPERHEATER LOCOMOTIVE; NORTH-EASTERN RAILWAY—ERRATUM.—We regret that it was stated last week in our description of this locomotive (page 50 *ante*) that the cylinders were composed of three castings. All three cylinders and steam chests are, we are informed, embodied in a single casting.

ALLOY STEELS FOR LIGHT ARMOUR.—In co-operation with the United States Bureau of Mines and the Navy Department, the Bureau of Standards, says *The Iron Age* is studying the properties of special alloy steels suitable for light armour. The majority of these steels contain zirconium, while others contain molybdenum, boron, cerium, &c. About 150 ingots have been made by the Bureau of Mines experiment station at Ithaca, N.Y., and have been rolled into plates of ½ in. or ¼ in. thick at the Bureau of Standards. The properties of these are being thoroughly examined, including the mechanical properties heat-treated and annealed, hardness, resistance to impact, microstructure, chemical and thermal analyses. In conjunction with the ballastic tests to be made by the Navy Department, valuable data are being obtained for the manufacture of light armour plates.

THE ALDWYCH BUILDING SITE.—The last large building site in Aldwych (facing the island site of the Bush Company and Australia House) has been secured for British industry; the offer for this, made by Agricultural and General Engineers, Limited, having been accepted by the London County Council. This important site has a frontage on Aldwych of about 213 ft., and an approximate area of 30,000 ft. The Board of the Agricultural and General Engineers, Limited, with which company are associated the well-known businesses of Aveling and Porter, Limited; Barford and Perkins, Limited; E. H. Bentall and Co., Limited; Blackstone and Co., Limited; Charles Burrell and Sons, Limited; Richard Garrett and Sons, Limited; J. and F. Howard, Limited, and others, have decided to erect on the site commodious office and showroom accommodation. The architects are Messrs. Josiah Gunton, F.R.I.B.A., and W. H. Gunton, A.R.I.B.A., Finsbury House, E.C.

THE SURVEYORS' INSTITUTION.—A Special Committee, composed of members and non-members of the council, in equal numbers, with the president of the Institution as chairman, is being set up to consider the various proposals which were made at the ordinary general meeting on December 15 last, with regard to the future activities of the Institution. This committee will report to the council, and their proposals will then be submitted to the country branches for their consideration. The Institution having been asked to co-operate with the Royal Institute of British Architects, the Society of Architects, the Architectural Association and the Architects' and Surveyors' Assistants Professional Union on the Welfare Committee, which will act as a Whitley Council between employers and employed in the two professions, the president, Mr. Andrew Young, has been nominated to represent the Institution in the first instance.

NOTICES OF MEETINGS.

THE ROYAL SOCIETY OF ARTS.—Monday, January 19, at 8 p.m.: Cantor Lecture, "Aircraft Photography in War and Peace," by Captain H. Hamshaw Thomas, M.B.E., M.A., F.G.S., Fellow of Downing College, Cambridge, and formerly of the Royal Air Force. (Lecture I. "The Taking and Production of Aerial Photographs.") Wednesday, January 21, at 4.30 p.m.: Ordinary Meeting. "Ancient Cottages and Modern Requirements," by Mr. Alfred H. Powell. The Right Hon. Earl Ferrers will preside.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, January 20, at 5.30 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, W.C. 2. The following paper will be read: "Spontaneous Ignition Temperatures of Liquid Fuels," by Mr. Harold Moore, M.Sc.Tech., A.I.C.

THE LIVERPOOL ENGINEERING SOCIETY.—Wednesday, January 21, at 8 p.m., at the Royal Institution, Colquitt-street. A discussion will be held on the Council's Report on "Engineering Training." Copies of this Report may be obtained on Members making application to the Hon. Secretary.

THE ASSOCIATION OF ENGINEERING AND SHIPBUILDING DRAUGHTSMEN.—Wednesday, January 21, at 7.30 p.m., at Birkenhead, Cheshire, Mr. Peter Doig (general secretary of Association) on "Screw Propellers," being an official Association Lecture. Thursday, January 22, at 7.30 p.m. at Milton Hall, Deansgate, Manchester, Mr. Douglas Wilson, A.M.I.Mech.E., on 'Steam Raising from Waste Material,' being an official Association Lecture. Friday, January 23, at 7.30 p.m., at the Grammar School, Chesterfield, Mr. Ewart S. Andrews, B.Sc.(Eng.), Member of Council of Concrete Institute, on "Reinforced Concrete Design."

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, January 21, at 5 p.m., at the Rooms of the Royal Astronomical Society, Burlington House, Piccadilly. Business: (1) Ordinary Meeting for the election of new Fellows; (2) Annual General Meeting; (3) Report of the Council for 1919; (4) Proposed New Bye-Law; (5) Election of the Council for 1920; (6) Presentation of the Symons Medal, awarded to Dr. H. H. Hildebrandsson; (7) Address on "Pioneers in the Science of Weather," by Sir Napier Shaw, D.Sc., F.R.S., President.

THE CONCRETE INSTITUTE.—Thursday, January 22, at 7.30 p.m., in the Lecture Hall at Denison House, 296, Vauxhall Bridge-road, ninety-first Ordinary General Meeting. Paper by Dr. J. S. Owens, F.R.G.S., F.G.S., on "The attrition of Concrete Surfaces, exposed to Sea Action" (lantern).

THE ROYAL SOCIETY.—Thursday, January 22, at 3.30 p.m., Special General Meeting—His Royal Highness the Prince of Wales having expressed his intention to attend for admission into the Society on that day. At 4.30 p.m., papers: Professor E. G. Coker, F.R.S., and Mr. K. C. Chakko, "The Stress-Strain Properties of Nitro-Cellulose and the Law of its Optical Behaviour"; Mr. S. Marsh, "On Alternating Current Electrolysis," communicated by Professor E. H. Griffiths, F.R.S.; Mr. W. H. Eccles and Mr. J. H. Vincent, "The Variations of Wave-Length of the Oscillations Generated by Three Electrode Thermionic Tube due to Changes in Filament Current, Plate Voltage, Grid Voltage or Coupling," communicated by Professor W. H. Bragg, F.R.S.; Mr. S. D. Carothers, "Plane Strain. The Direct Determination of Stress," communicated by Professor A. E. H. Love, F.R.S.; Mr. F. Horton and Ann C. Davies, "An Investigation of the Effects of Electron Collisions with Platinum and with Hydrogen, to ascertain whether the Production of Ionisation from Platinum is due to Occluded Hydrogen," communicated by Mr. C. T. R. Wilson, F.R.S.; Mr. L. Bairstow, F.R.S., Mr. R. H. Fowler, and Mr. D. R. Hartree, "The Pressure Distribution on the Head of a Shell moving at High Velocities."

THE INSTITUTION OF MINING AND METALLURGY.—Thursday, January 22, at 5.30 p.m., at the Rooms of the Geological Society, Burlington House, Piccadilly, London, W. 1. The following paper will be submitted for discussion: "Froth Flotation: Its Commercial Application and its Influence on Modern Concentration and Smelting Practice," by Mr. Walter Broadbridge, Member.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, January 22, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W., "Transformers for Electric Furnaces," by Mr. J. L. Thompson, M.Sc., Associate Member.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, January 22, at 7.30 p.m., at 39, Victoria-street, S.W. 1, "Evaporation in the Chemical Industry," by Mr. J. A. Reavell, M.I.Mech.E.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, January 23, at 9 p.m., Friday Evening Discourse by the Hon. Sir Charles Parsons, K.C.B., D.Sc., LL.D., F.R.S., M.R.I. The subject is "Researches at High Pressures and Temperatures." Afternoon Lectures, at 3 p.m.: Tuesday, January 20, Sir John Cadman, K.C.M.G., D.Sc., M.Inst.C.E., on "1. Modern Development of the Miners' Safety Lamp"; Thursday, January 22, Mr. Richard R. Terry, Mus.Doc., F.R.C.O., on "Renaissance Music in Italy and England" (with musical illustrations) (Lecture II); Saturday, January 24, Mr. Alfred Noyes, on "2. Aspects of Modern Poetry."

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 23, at 6 p.m., at the Institution, Storey's Gate, St. James's Park, S.W. Paper to be read: "Recent Advances in Utilisation of Water Power," by Mr. Eric M. Bergstrom, of London, Associate Member.

BELT-DRIVEN SINGLE-CRANK FOUR-STAGE AIR COMPRESSOR.

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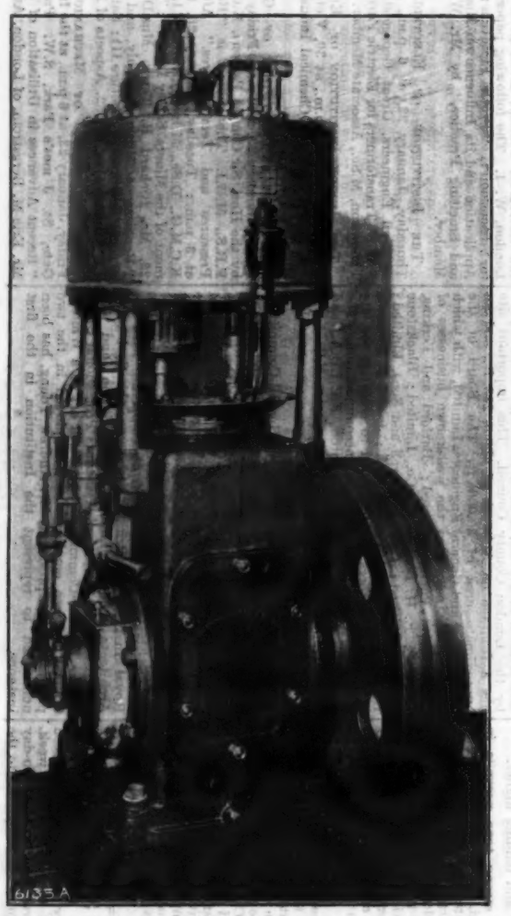
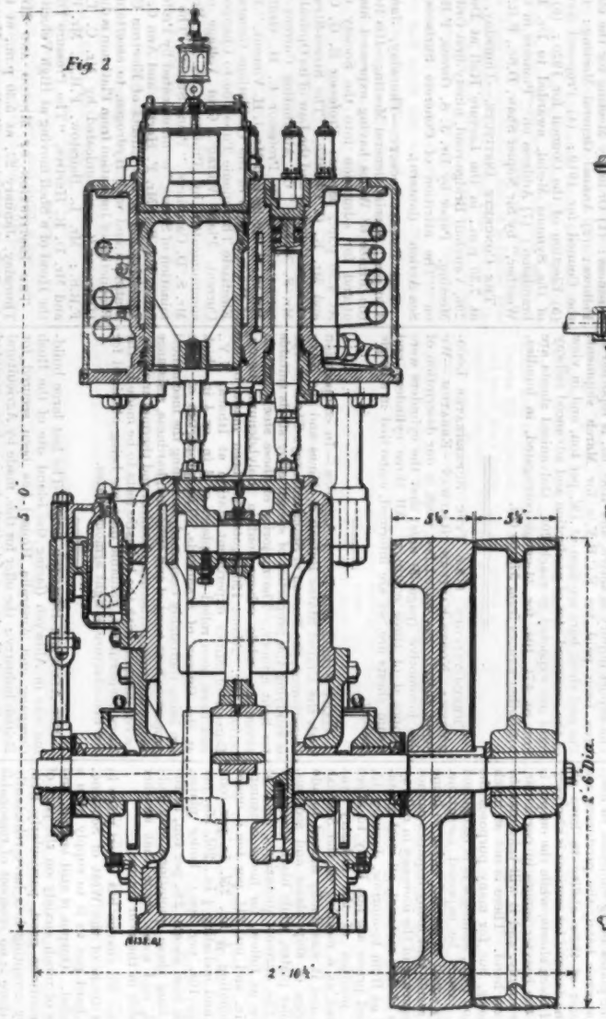
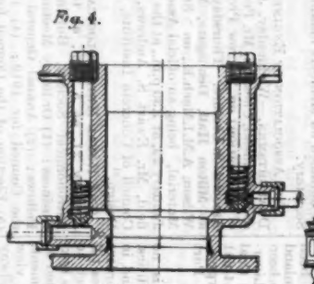
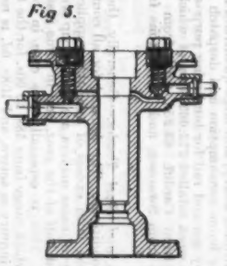
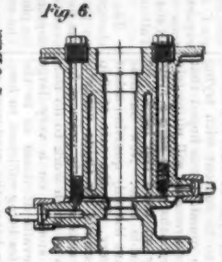
(*For Description, see Page 82.*)











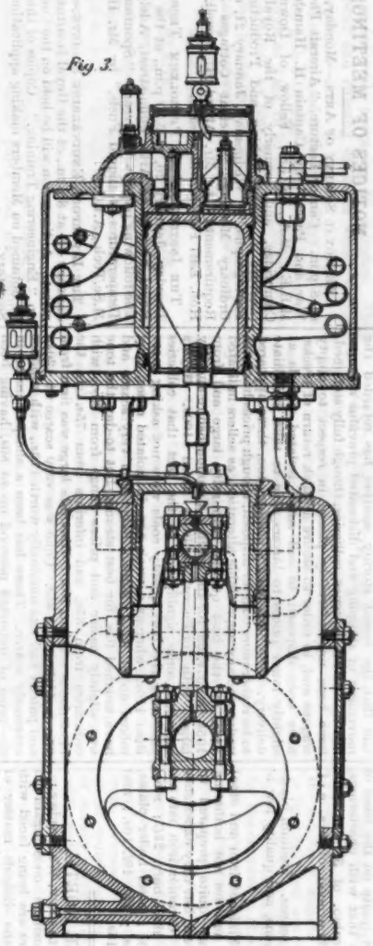


FIG. 1.

BRITISH PRODUCTION OF PIG-IRON AND STEEL.—The National Federation of Iron and Steel Manufacturers, Temple Bar House, 23 to 28, Fleet-street, E.C. 4, state that the output of pig-iron for the year, 1919, the figures for December being approximate, was 7,370,000 tons (in 1913 it was 10,260,000 tons, and 9,072,000 tons in 1918). The total steel ingot output for 1919, the figures for December being also approximate, was 7,880,000 tons (in 1913, 7,664,000 tons and in 1918, 9,891,000 tons).

GERMANY AND HER FOREIGN MARKETS.—According to *The Board of Trade Journal*, it is generally assumed in the German Press that apart from the danger of an "economic war" on Germany, there is also what is termed a "psychological epidemic" with which entire nations are afflicted. This is resolving itself into an aversion for everything German, which will continue for some time to lead to a situation in all economic life similar to a state of war. To overcome this prejudice many suggestions have been made, some of which have been carried out. The first was the idea of selling German merchandise under the trade marks of neutral countries. This, it is stated, has necessarily been abandoned. Another project is the establishment of branch factories in neutral countries. But here again, Switzerland, for example, has taken measures to prevent articles produced by such branch plants from bearing marks indicating Swiss manufacture. Such articles are not admitted to the Sample Fair at Basle, and it is anticipated that there will be future legislation, at least in France and England, to prevent the entrance of these pseudo-Swiss products. It is hoped, however, that it may be possible to overcome these difficulties by founding in neutral countries local (national) firms under the control of dummy directors. For the period immediately following the war, at least, it is urged that everything points to the neutral as the proper representative of German firms. He can enter France and England without difficulty, and can sell his customers German goods, which naturally speak for themselves.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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TELEPHONE NUMBERS—3603 and 8596 GERRARD.

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NOTICE.

Owing to the enormous increases in the cost of paper, engravings, and printing charges generally, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 9d. to 1s. per copy. This increase dates from and includes the issue of Friday, January 2, 1920. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 83.

ENGINEERING.

FRIDAY, JANUARY 16, 1920.

FUELS FOR MOTOR VEHICLES.

THERE would be little to say or write on the subject of fuels for motor vehicles if petrol were available in unlimited quantities at a price of a few pence per gallon, and even if we could be sure of a steady supply at the present high price the matter would hardly be one of vital importance. The real situation, however, gives considerable cause for disquiet, as there can be little room for doubt that the present rate of consumption will exhaust existing supplies in a comparatively few years. New sources of petroleum may, of course, be discovered and developed, but these will have greatly to exceed the sources which become exhausted in order to keep pace with the future demands of motor-car users alone, and if we add to these the probable requirements of the aviation industry there is every likelihood of a shortage—to say the least of it. Moreover, the price of petrol, like that of all other commodities, will follow the law of supply and demand, which has already operated to increase the cost to the user from a few pence per gallon in the early days of motoring to the present price of over 3s. a gallon. With an increasing demand, and a diminishing supply, prices will continue to rise, and indirectly, this must have an adverse effect on our whole national life.

In these circumstances it is pertinent to consider what means are available for eking out our supplies of petrol so as to delay, or prevent, its complete exhaustion. Of the alternative motor fuels so far tried benzol appears, at first sight, to be the most promising, since its properties most nearly resemble those of petrol. Recent road trials have shown that it can be employed without any deleterious effect in an engine designed for petrol, but its present price, which is very little less than that of petrol, does not tend to encourage its widespread use. Moreover, being a by-product of gas manufacture and coke-making, the supply available is naturally governed by those industries. However, it has the distinct advantage of being a home-produced fuel, and it must certainly be considered as a factor likely to affect the problem of motor fuel supply. Paraffin and heavier oils are also possible fuels, but those produced from petroleum, at all events, suffer from the drawback that if extensively employed the demand would probably soon overtake the supply, with the usual effect on prices.

The one liquid fuel which appears to be free from any objection from the point of view of future supply is alcohol. The great advantage of alcohol as a motor fuel is that it can be produced in almost unlimited quantities from innumerable vegetable substances, and although it may not be practicable to manufacture it in sufficient quantities in this country, it would certainly be possible to supply our whole needs from the resources of the British Empire. Dr. T. Blackwood Murray, in a recent address to the Institution of Engineers and Shipbuilders in Scotland referred to on page 690 of our last volume, expressed the opinion that denatured alcohol fuel could be supplied to consumers in this country at the price of 1*s.* 3*d.* per gallon, and this should be a distinct incentive to automobile engineers and others to overcome any remaining technical difficulties attending its use.

Although alcohol appears likely to become the chief motor fuel of the future its present high price, which is, of course, largely due to the excise, puts it quite out of court for the time being. Solid fuels, on the other hand, although not exactly cheap and plentiful at the moment, are to hand in ample quantities in normal times. Coal may be used for road traction in a variety of ways. It can be employed directly, either in the raw state or in the form of coke, for firing the boilers of steam wagons, or it may be used to generate electric energy for charging the accumulators of electric vehicles. In either case the fuel costs are lower than those of similar vehicles driven by petrol. Another method of using coal, and that with which we are most concerned at the moment, is in the form of gas. Gas stored in steel cylinders, or in flexible containers, can, of course, be used in motor-car engines of ordinary design, and for certain classes of work it is probably a reasonable proposition. The cost of the compressing plant and the weight of the cylinders carried are the main objections, and these are of least importance when a considerable number of vehicles have to maintain a regular service over a comparatively short route.

What appears to us to be a much more promising method of utilising solid fuel in motor vehicles was dealt with in a paper read by Lieutenant-Colonel D. J. Smith last week before the Institution of Automobile Engineers. In this paper, the publication of which was commenced on page 59 *ante*, and is completed in the present issue on page 92, Colonel Smith describes the suction producer plant he has designed for road transport work, and also gives some particulars of its use in this connection. The advantages and disadvantages of the system are fully set out in the paper, so that it is unnecessary for us to refer to all of them here. Of the former, the most obvious is, of course, the extremely low fuel cost, which in the case considered of a 5-ton lorry, works out to slightly over 0·09*d.* per net ton-mile, whereas the corresponding figure for a petrol lorry of equal capacity is 1·2*d.* To equalise these fuel costs it would be necessary to obtain petrol at the price of 2·6*d.* per gallon (not 2*s.* 6*d.* as was unfortunately printed in error in Table I, on page 59 *ante*). Even in comparison with a steam wagon the fuel cost with the producer plant is only about one-eighth as great. Fuel costs, however, are not the only *desiderata* in the running of a motor vehicle. Suction gas has certainly a number of drawbacks in comparison with petrol, the only questions being whether or not the disadvantages can be eliminated, and, if not, whether they more than outweigh the saving in fuel. The chief drawbacks are the time required for starting up from cold, the weight of the plant carried on the vehicle, the additional weight of fuel and water which must be carried for a given journey, and the time and trouble involved in cleaning the plant. What these drawbacks amount to may be gathered from the paper, and they certainly appear to be of little consequence in comparison with those associated with a steam vehicle.

Unfortunately the paper gives no information as to the degree of reliability to be expected from the system, a point which, it appears to us, would be one of the first to be raised by a prospective user, especially if he had had experience with stationary producer plants. Obviously low fuel cost would cease to be attractive if accompanied by frequent breakdowns on the road. It would, we think, be extremely interesting to have particulars of a long series of runs under ordinary working conditions, with notes as to the causes of all compulsory stoppages. It would then be possible to judge to what extent the troubles could be eliminated by improved design of the plant. Some such information is given in the Report of the Inter-Departmental Committee on Gas Traction, but as the vehicle used was not itself in good running order, and the suction plant was of an improvised nature, the results obtained are hardly fair to the system. In the trials

dealt with in the report, seven trips, totalling 277 miles, were run over a period of about a month, under conditions resembling those which obtain in an ordinary goods delivery service. In the country, or in fairly open traffic, no difficulty was experienced in maintaining an average speed of 10·5 m.p.h. The gas production was also ample to meet all conditions of travelling. As might be expected, incidental troubles were experienced, most of which the Committee admitted were due to defects of construction. Much of the difficulty was due to the lack of means for adjusting the fuel feed to the rate of consumption of the gas, and could thus be eliminated by modification of design, but for further particulars we must refer our readers to the report itself.

The main point is that it is possible to produce a suction-gas plant which can be used on heavy motor vehicles, and if such plants can be shown to be sufficiently reliable and convenient under ordinary working conditions the resulting economy should materially affect the question of road transport. The employment of suction plants on heavy vehicles, for which they appear to be best suited, would release a considerable quantity of petrol for use on lighter vehicles and for other purposes, but from the remarks made by Mr. H. S. Brown, of Messrs. Brown and Wade, Limited, during the discussion of Colonel Smith's paper, we understand that a plant weighing only ¾ cwt. has already been tried on a Ford car with promising results.

The most satisfactory fuel for suction gas installations or motor cars is anthracite beans, but gas-coke or charcoal are also quite suitable for the work. The use of peat, maize cobs, and straw is also referred to in the paper, and many other waste fuels could doubtless be employed, especialy if previously carbonised as suggested by Dr. W. R. Ormandy in the discussion of the paper. This feature is obviously one of the utmost importance in those countries where coal and petrol are either quite unobtainable, or only available in small quantities at exorbitant prices. Generally the paper was sympathetically received, though some of the speakers were distinctly critical of the design of the producer. Doubtless the latter is capable of improvement, but Colonel Smith's object, we gather, has been not so much to obtain the maximum possible fuel economy as to design a producer capable of working under the exceedingly onerous conditions of road service, and we think it must be admitted that the results obtained in this respect are distinctly encouraging. One speaker, however, frankly disapproved of the whole idea, and even criticised the figures given because the cost of the water used had not been taken into consideration. He much preferred petrol to producer gas and so, we imagine, would Colonel Smith and everyone else, if they thought that the former would always be available at a reasonable price. As it is, the question of fuels for motor cars is a branch of the whole fuel problem which automobile engineers must consider in earnest. It is obviously of little value to embark upon a huge programme of mass production of motor cars unless an adequate supply of fuel for them is assured.

MERCHANT SHIPBUILDING OF THE WORLD.

PERHAPS the most interesting feature of Lloyd's Shipbuilding Returns for the quarter ended on December 31 last is that Great Britain has now regained her foremost position in the world of shipbuilding, having 757 vessels under construction, with an aggregate gross tonnage of 2,994,249. This latter figure is 27,734 tons in excess of the tonnage now in hand in the United States, the figure for that country having fallen from 3,470,748, tons at the end of September, to 2,966,515 tons at the end of December. The British tonnage, on the other hand, has increased by 177,476 during the last quarter, and is roughly 1,014,000 tons greater than the corresponding figure for the end of 1918. In all other countries of the world including the United States and the British Dominions, but excluding Germany for which country the figures are not yet available, there are 1,381 vessels, making 4,867,114 tons in all, under construction, so that the British tonnage building now amounts to over 38 per cent. of the world's total. The shipbuilding industry, at the moment, is thus in a highly satisfactory condition, and although some of the vessels building here are, of course, for foreign owners, it would seem that a very determined effort is now being made to regain our pre-war position in the world of shipping.

With regard to the number of vessels completed during the quarter there is, however, rather less cause for congratulation. The vessels launched number 153 and have an aggregate tonnage of 459,354, which is 43,309 tons more than in the previous quarter, but 68,846 tons less than in the June quarter. The complete statistics for the whole year are not yet available, but by adding the quarterly returns it appears that 595 vessels, totalling 1,608,606 tons, were launched during 1919. This is but a slight improvement on the previous year, for which the figure was 1,348,120 tons. More than one-third of the total British tonnage now under construction is building in Clyde shipyards, the figures for Glasgow being 155 vessels, totalling 683,914 tons, an increase of 6·5 per cent. on the previous quarter, while those for Greenock are 68 vessels, totalling 337,905 tons, which are rather lower than the figures for September. The Tyne comes next with 114 ships, of an aggregate tonnage of 593,189 in hand, the increase in this case being 56,229 tons (10·5 per cent.) as compared with the figures for the previous quarter. In the case of Belfast and Londonderry the increase amounts to 24,350 tons (7·8 per cent.), there being 39 ships in hand with a total tonnage of 336,700. At Sunderland 65 ships, making 299,465 tons, are on the ways, which is 13,075 tons (4·56 per cent.) more than were building there in September last, while at Middlesbrough there has been a slight decrease in tonnage building. The figures for the latter port are now 51 ships, totalling 225,920 tons, as compared with 55 vessels, making 227,565 tons at the end of September. Hartlepool and the Barrow district both show notable increases during the quarter, the figures for last quarter being 20 ships (90,100 tons) and 10 ships (84,675 tons) respectively, as compared with 18 ships (77,320 tons) and 7 ships (55,295 tons) for the previous quarter. The increase in the case of Barrow, it will be noted, amounts to well over 50 per cent. At Liverpool the work in hand amounts to 76,380 tons (35 ships), while the corresponding figures for Hull are 62,733 tons (68 ships). The Hull tonnage has decreased by approximately 6 per cent. during the quarter, and the Liverpool tonnage has increased by a similar amount.

Excluding the United States, the first position in shipbuilding in foreign countries is taken by Holland, where 126 vessels, of 328,338 tons in all, are now under construction. The next place falls to Italy, which now includes Trieste, the figures for this country being 125 ships, making 314,547 tons. Japan follows with 64 ships, totalling 309,474 tons in hand, while the British Dominions, which have 113 ships with an aggregate tonnage of 251,480 in hand, take fourth place. The only other countries having more than 100,000 tons of shipping under construction are France, with 216,775 tons, Sweden with 110,765 tons, Spain with 107,463 tons and Denmark with 100,335 tons.

THE MICROSCOPE: ITS DESIGN, CONSTRUCTION, AND APPLICATION.

WHEN the members of four societies, the Faraday Society, the Royal Microscopical Society, the Optical Society and the Photomicrographic Society, together with the Optical Committee of the British Science Guild, were assembling two days ago in the rooms of the Royal Society for a general discussion on the Microscope, and looking at the list of papers and exhibits, they may have asked themselves whether the Faraday Society, to whose president, Sir Robert Hadfield, the initiation of the joint meeting is due, had been wise in inviting the co-operation of the four other bodies. There were 10 addresses and papers to be dealt with in the afternoon session, from 4.15 p.m. to 6.30 p.m., and 16 more papers and the general discussion to be disposed of in the evening session beginning at 8.15 p.m. Fortunately there was less overlapping in the contributions than might have been feared, and most of the authors had restricted themselves in their communications, though the reiteration of generalities was hardly avoidable. The interest taken in the very instructive exhibition, which was opened at 2.15 p.m., was not affected by the fact that the annual exhibitions of the Physical and Optical Societies had been resumed the previous week; most of the 47 exhibitors of last Wednesday had not participated in the previous display, and the exhibition was, in fact, kept open till Thursday afternoon to satisfy a generally-expressed wish. Sir Robert Hadfield took the chair punctually at 4.15 p.m. and presided over crowded meetings both in the afternoon and evening. The proceedings closed at 10.25. The chief problems discussed were those of the manufacturer and the user of the microscope, but strictly scientific questions like those of resolution were by no means neglected. Like the speakers we shall have to restrict ourselves in our comments.

Sir Robert Hadfield. Bart., D.Sc., D.Met., F.R.S., delivered the introductory address and presented two further communications. He opened his address with a brief history of the societies participating in the discussion, dwelt on the unenviable position of the British optical industry at the outbreak of the war, and proceeded to his main subject, a review of the history of the microscope from ancient days up to the present time, with particular reference to the application of the microscope to modern metallurgy and to subsidiary problems. The long address, which was illustrated by 14 plates of historical interest and supplemented by a bibliography, might be said to emphasise the familiar *dicta* or *dictum*—for finally the two points amount to the same—that there is little new under the sun, and that the obvious conclusion to be drawn from a new observation and the application to be made are frequently delayed for so long a time that they finally appear in the light of new discoveries. The microscope, or the lens at any rate, must have been known in ancient times, Sir Robert pointed out; the delicate ancient gems could not have been cut without their use, lenses of rock crystal were found in the ruins of Nimrod's palace, and Seneca, Plinius and others referred to the use for magnification of hollow glasses filled with transparent liquids. Convex spectacles were invented in Italy about 1300; Leonardo da Vinci (who died 1519) studied the optical properties of lenses; but the first evidence of copper plates having been engraved with the aid of magnifying glasses was found in a book published by Hoefnagel at Frankfurt in 1592. The invention of the microscope, by the Dutch spectacle makers Zacharias (father and son—miscalled Jansen, Sir Robert remarked) probably followed in 1619; by 1632 Leeuwenhoek had done wonderful work with his 27 microscopes in which he attained magnifying powers of 160; Réaumur studied the structure of chilled iron castings under the microscope in 1722; and Henry Clifton Sorby, of Sheffield, prepared sections of rocks in 1849, and of metals in 1864, for the study of petrography and metallography; but his work did not attract attention until in 1877. Martens (Berlin), and later Osmond and Le Châtelier (Paris) independently and anew developed the craft which Sorby had invented. We cannot follow Sir Robert in his *précis* of the modern work on the microscope, but we note his statement that, during the war, the manufacture of microscopes was not permitted in this country until after the conclusion of the armistice, other optical work being more pressing.

Sir Robert's second contribution was on the "Great Work of Sorby." His third, a joint paper by himself and Mr. T. G. Elliot, F.I.C., on "Photomicrographs of Steel and Iron Sections as High Magnifications," was illustrated by a large number of magnificent slides, some of which we are able to reproduce on our Plate VII. Experienced workmen, Mr. Elliot stated, could, from the appearance of a fracture, detect by the eye differences in the carbon percentage of 0·1 per cent., and even of 0·05 per cent. Metallographers generally used magnifications of 1,000 or 1,500; but Sir Robert and Mr. Elliot had been able to obtain photographs of 5,000 and 8,000 magnifications. The diameter

of the actual field shown on a 3¼-in. circle photograph at this magnification was only 1/2460 in., the actual area of the field examined was 0·00000013 sq. in., the polished section under the microscope being about ½ in. square. If the whole of that area were magnified 8,000 times, the area covered would be 55 yards square, almost ¾ acre. The objective yielded an enlarged image, which the eyepiece further enlarged. The photomicros shown were obtained by eyepiece magnification and extra camera-extension of the images given by a 2-mm. or 1·5-mm. objective. If the objective produced a blurred image, the blur was magnified; high magnification obtained by projecting a lantern slide could not bring out further detail. That depended upon the resolving power of the objective, as some of Sir Robert's photographs exemplified. The first one we reproduce (Fig. 1) has the historical interest of having been taken by Sorby; it represents a longitudinal section of a blister steel at magnification 9. Of Sir Robert's four photographs of an annealed alloy steel (0·84 carbon, 1·12 Cr), taken at magnification of 1,000, 1,500, 5,000, 8,000, we reproduce Fig. 2, the last, in which the magnification, as he remarked, had taxed the lens somewhat beyond its capacity; the structures of the fine lamellar and sorbitic pearlite come out well, though. Photomicrographs of diatoms had been obtained by transmitted light, at 5,000 magnifications, but for steel such magnifications were novel. To obtain them we wanted high resolving power and properly-compensated eye-pieces. The next important point was the preparation of the specimen, the etching—to remove the amorphous layer and to bring out the various constituents; the etching should not be too deep, lest the pits and furrows produced extended beyond the depth range of focus. The best results were obtained with alcoholic solutions of 5 per cent. of picric acid; in other photographs exhibited nitric acid and metanitrobenzolsulphonic acid (also 5 per cent. solutions) had been used. The intense illumination required was best obtained by the use of a 20-ampere carbon lamp, hand-fed; mechanical feeds were never firm and free from vibration and were apt to require readjustment at the critical moment; with cored carbons 70 volts alternating answered as well as continuous currents; the authors mentioned that they had no particular experience with tungsten arcs and mercury vapour arcs.

The vertical illuminator should be a plain glass disc, not a prism; the iris diaphragm of the illuminator should not be closed more than necessary for obtaining a sharp field. For apochromatic objectives Sir Robert recommended a blue screen (light filter) and ordinary photographic plates, the specimen being focussed first on the ground glass screen of the camera and finally adjusted with the aid of the clear-glass screen and the focussing magnifier.

With respect to our photographs we may add that the black constituent of Fig. 3, Plate VII, showing the structure of a grey casting (containing 3·5 C, 2·5 graphite, 2·82 Si, &c.) is graphite, the ground mass pearlite; three other photographs of the same specimen (at magnifications 100, 600, 1,500) clearly demonstrated the advantages of higher magnifications. Fig. 4 exemplifies the martensite and troostite of a quenched carbon steel (0·9 C, 0·27 Si, 0·29 Mn) with a magnification of 8,000. Figs. 5 and 6 illustrate the microstructure at 5,000 magnifications of the same carbon steel (1·41 C, 0·38 Mn) in two different conditions. In Fig. 5 the steel was annealed, and the structure marks a typical pearlite and cementite; in Fig. 6 the steel was quenched and tempered, producing a structure of mixed troostite and cementite. The three last figures were all taken with a 1·5-mm. apochromate. Sir Robert's further photographs demonstrated that little was gained in general by enlargements of negative; in the case of complicated subjects direct photomicrography seemed preferable. Though these high magnifications had so far not led to any really new discovery, Sir Robert said, in concluding, there was evidently a wide field open for further investigation, especially as regards higher resolution and the use of ultraviolet light which might reveal unsuspected phenomena.

(To be continued.)

PROGRESS IN LOCOMOTIVE DESIGN ON THE PENNSYLVANIA RAILROAD.

In 1916 we gave in our columns a detailed description of a design of 2-8-2 type of locomotive, which was the result of studies of tests made on the Pennsylvania Railroad testing plant at Altoona.* Mr. J. T. Wallis, general superintendent of motive power of the company, later produced another type of engine, which has been the logical outcome of the use of the former type in service. The most interesting departure in the newer type is the limitation of the cut-off of steam in the cylinders to about 50 per cent. of the stroke. The "L–1s" class above referred to has been found in practice to work for a very large portion of its time at nearly full cut-off. This is because the engines are in use mainly on hill sections, usually in helper service. The idea in the new class was to design an engine which would work normally with a much more economical cut-off, and the limit was placed at about 50 per cent. When "hard over," therefore, the new type of engine uses steam expansively, but has been designed to give a total power equal to and, in fact, exceeding the earlier class, in which the bulk of the work had to be done in full gear without expansion.

The new class is of the 2-10-0 type, the weight at the trailing end therefore being utilised for adhesion. The total weight of this, the "I–1s" class, is 371,800 lb., or an increase of 15·9 per cent. on the previous type, while the weight on the coupled wheels is increased by no less than 42·4 per cent., to 342,050 lb. This is important in view of the large increase in cylinder volume of the new class. The decapod, or 2-10-0 engine, has cylinders 30½ in. by 32 in. As the former engines had cylinders 27 in. by 30 in., this is equivalent to an increase of volume of 37·6 per cent. From indicator cards taken on the new engine with the reversing gear right over, *i.e.*, giving a cut-off of about 50 per cent., the mean effective pressure appears to be about 75 per cent. of the boiler pressure. This figure is used, therefore, for calculating the tractive effort in this case, instead of the figure of 85 per cent. more commonly adopted. Taken as it is from cards, this 75 per cent. includes the drop between the throttle and the steam chest. Using this figure, the tractive effort works out at about 90,000 lb., the ratio of adhesive weight to tractive force being 3·8. The driving wheels are 62 in. in diameter. The boiler pressure is 250 lb. per square inch.

When in full gear, as designed, this engine develops, at 7·4 m.p.h., nearly 1,744 i.h.p. on test. The corresponding figure for the previous class, which had a boiler pressure of 205 lb. per square inch, is 1,220, so that the new engine has an advantage of 43 per cent. in power at starting speeds. At 25 m.p.h. the indicated horse-power rises to 3,486 in the case of the "I–1s" class, and only 2,755 in the case of the "L–1s" class. At 7½ m.p.h. a draw-bar pull of 76,000 lb. was measured for the new class. Tractive force curves when worked out for this new type show no greater divergence from the straight than in the former class, thus there is no greater tendency to slip than in the previous design, though the overall results are much higher.

In order to secure valves and motion to meet the objects aimed at, the steam lap, with a valve with 6-in. travel, had to be made 2 in. The lead of the valves is $\frac{1}{8}$ in., and the exhaust lap ¼ in. The valves have inside admission, and are of the piston type, 12 in. in diameter. With the object of ensuring good starting small auxiliary ports were introduced. These are only ½ in. by 1½ in., placed 1¾ in. distant from the main ports, on the inside, and are uncovered by the valve before the main port. They admit steam to the cylinders under all conditions of running, but the amount is not sufficient to impair the economical working of the engine. With the high boiler pressure and large cylinders, the crank-pin pressures were unusually high. To take care of these the crank-pins were made no less than 10 in. in diameter by $8\frac{5}{8}$ in. long, while the side-rod pins were 11 in. in diameter by 6^{11} in. long.

The boiler, which has a grate area of 70 sq. ft. or the same as the "L–1s" class, has increased superheater surface and tube surface, but slightly decreased fire-box surface; the total change in surface worked out at 5,423 sq. ft. in the new class compared with 4,847 in the old, or a difference of about 12 per cent.

On test, the new engine has proved to be an improvement in every sense on the old. It develops greater power, has a higher superheat, and is more economical both as regards steam and coal consumption. With 250 lb. steam pressure corresponding to a temperature of 406 deg., the superheat attained was about 280 deg. The saving in steam over the "L–1s" type amounts to 38 per cent. in full gear, in which the greater part of the work is done. This difference naturally decreases as both engines are notched up. The engine was fitted with a Duplex stoker, with which an output of power was obtained far greater than is possible with hand-firing over any protracted period. At low rates of firing, however, it was found that hand-firing was more economical.

On the subject of auxiliary ports we may remind our readers that in the Göldsdorf two-cylinder compound small auxiliary ports in the low-pressure cylinder formed an essential feature of the starting gear. These ports were designed to be uncovered only when the lever was in full gear, and they admitted live steam direct into the low-pressure steam chest, in order to secure a good starting effort on that side of the engine. In the Pennsylvania engine, as we have remarked, the auxiliary ports are always uncovered while the engine is running.

* See ENGINEERING, Vol. cii, page 98 *et seq.*

THE PHYSICAL AND OPTICAL SOCIETIES' EXHIBITION.

(Concluded from page 57.)

We now propose to conclude our comments on the exhibition of apparatus held by the Physical and Optical Societies on Wednesday and Thursday of last week.

Prominent among the precision instruments of Messrs. H. Tinsley and Co., of Werndee Hall, South Norwood, S.E. 25, were several potentiometers, and among these the thermoelectric compensating potentiometer especially made recently for the National Physical Laboratory. Potentiometers are bridge arrangements designed for measuring small electromotive forces like those of thermocouples by balancing the force with the aid of resistance against the electromotive force of a normal cell. This is done in a divided circuit, as proposed by H. Hausrath in 1905, and the Tinsley potentiometer is based upon the apparatus described under the name of compensation apparatus by H. Diesselhorst, of the Reichsanstalt, in 1908, which embodied the improvements proposed by W. P. White (*Physical Review*, 1908), for eliminating any thermoelectric forces due to moving contacts and resistance fluctuations in the potentiometer itself. The current divides, in the instrument, in two branches so arranged, apparently symmetrical, that the current on the right-hand branch is one-tenth of that in the left branch; this proportion is maintained for any position of the switches by means of compensating coils which are put in circuit as other coils are cut out. For this purpose each dial is provided with top and bottom sets of coils, so connected that the respective contact arms automatically move in opposite directions; the total resistance is thus always maintained, and what is added to the E.M.F. of the one side is subtracted on the other; these variations only make up, in the potentiometer exhibited, 1·3 per cent. of a total of something like 10^{-6} volt. There are four pairs of dials which are called decades with respect to the ratio 1 : 10, and the instrument looks like a large resistance box; the range is 10,000 microvolts. The new vernier potentiometer of the firm resembles their universal potentiometer for alternating currents, but it dispenses with the usual slide-wire; all the resistances are brought to contact studs of copper, which are capped with sweated-on foils of a silver-gold alloy; the end of the contact arm is tipped with the same non-tarnishing alloy which looks like steel. There are three dials, of 0·1 volt, 0·001 volt and 0·0001 volt per stud respectively; the second, vernier, dial is shunted across any two studs of the first dial.

The Kelvin double bridge is a self-contained

instrument for expeditious low-resistance measurements. As regards the Drysdale-Tinsley non-inductive low-resistance shunts and their standardisation, Messrs. Tinsley, like other firms, experience great difficulty in obtaining suitable standard-resistance material (magnanin) in this country; manufacturers' guarantees may be hopelessly unreliable, temperature coefficients of 200 parts in 1,000,000 being found instead of the guaranteed maximum of 30. The striking features of the new variable and mutual inductors, instruments for measuring from 6 to 159 millihenry in self-inductance and from 0 to 34 millihenry in mutual inductance, are the ease of operation and of taking a reading.

The artificial telephone cable (60 miles), and the Gall and Tinsley artificial track circuit serve more technical purposes. The latter instrument brings 2 miles section of track line in any condition into the laboratory, with their extremities within a few inches of one another, and enables the electrical engineer to test his track-transformers, relays, regulating resistances, &c., in the laboratory instead of on the line itself, where he is constantly disturbed by the traffic and the weather. The instrument is made serviceable for both continuous and alternating currents, or in a simpler form, for continuous currents alone. The four dials (for resistance and inductance) of the instrument may be set to represent any condition of ballast resistance (up to 100 ohms) and rail resistance and impedance (up to 2 ohms) for a normal current at the relay ends of 5 amperes. By means of a testing set the actual track circuit when laid can be tested by a zero method, and the constants of the track (impedance and ballast resistance) can be balanced out. On the stroboscopic disc are marked four geometric figures, a square, a pentagon, a hexagon and a 30-point star. When any one of these figures turns through the angle subtended by two of its corners or points in the interval of 1/50th second, it will occupy the same apparent position at each flash and will appear stationary. Thus when the star rotates at 1/30th revolution in 1/50th second (1/3,000 minute), the star will appear stationary, and this will also occur at any multiple of 1/30th revolution per 1/50th second, that is to say, for 100 r.p.m., 200 r.p.m., 300 r.p.m., &c. At the intermediate values of 50 r.p.m., 150 r.p.m., 250 r.p.m., &c., the star will look double. The hexagon will appear stationary at 500 r.p.m., 1,000 r.p.m., 2,000 r.p.m., the pentagon and square at 600 r.p.m. and 750 r.p.m. respectively, with intermediate doubles and trebles. By combining stationary appearances the speed of rotation can be kept constant at any desired value, and any creeping off or up in the shaft speed will immediately become visible by the slow rotation of the geometric figures in the one or other direction.

The chief novelty of interest to the engineer of the Cambridge and Paul Instrument Company, of Cambridge and New Southgate, London, N.—the amalgamation of the firms of the Cambridge Scientific Instrument Company and Mr. Robert Paul dates from January 1, 1920—is the Cambridge electrical CO_2 recorder, another of the katharometer instruments devised by Dr. G. A. Shakespear, of Birmingham, for testing the composition of gases. Two cells are filled with gas, the one with the gas under test, the other with the standard gas. Each cell contains a platinum spiral, the two spirals being identical; if the same electric current be sent through both the spirals, they will be heated, and their rate of cooling will depend upon the density of the gas surrounding the spiral. The spirals form arms of a Wheatstone bridge, the galvanometer of which will be deflected to an extent depending upon the difference in the density of the two gases. In the CO_2 recorder the standard gas is air kept saturated with water, because the CO_2 in the flue gas is so saturated; the presence of carbon monoxide CO in the gas does not interfere with the indications because the density of CO happens to be the same as that of the nitrogen of the air. The instrument (Fig. 1) consists of a cylindrical box of iron, about 9 in. diameter, closed by a glass door. The box serves as aspirator, the water entering at D and leaving through the aspirator E at the rate of 5 gallons per hour; close to E, Fig. 1, is a U-tube indicating the pressure of the gas under test. The water-flow is regulated by device B, the water to run freely out of the fine tube and to trickle out of the wider tube. The gas enters the box at the top passes in the screwed plug G through a filter of glass wool before its admission into the katharometer H which is screwed into the chamber K. The katharometer is a cylindrical block of copper, into which two holes are drilled parallel to the axis. One of these holes contains air and is joined by a tube with the water cylinder F for maintaining the saturation; this cell is kept sealed, except for occasional examination. The flue gas is drawn through the other cell, which is joined to the U-pressure gauge mentioned. The spirals are made of 1 mil platinum wire (diameter 25·4 μ) and have a length of 8 mm. With the aid of the four binding screws underneath H and a four-lead cable, the box is connected with a thread recorder of the Cambridge Company, the

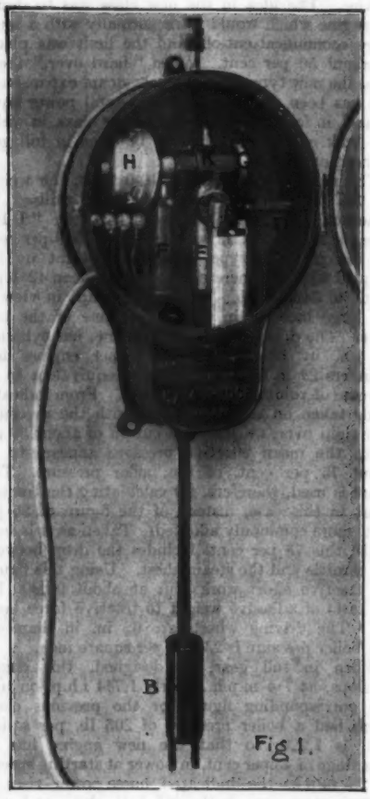


FIG. 1. CO_2 RECORDER.

pointer of which is depressed once every 1½ minutes to produce a dotted chart marking directly per cent. of CO_2. A 2-volt 40-hour battery is used to work the apparatus and for occasional testing with the aid of rheostats to meet fluctuations in the battery current. The CO_2 recorder has for some time been used by one of the large boiler firms for control testing and ordinary observations.

Another novelty, the flat-cutting microtome, characterised by a novel orientator integral with the microtome, is yet in the experimental stage. The instrument cuts perfectly flat sections in paraffin celloidin and in a certain class of non-embedded objects. The knife is supported at both ends and may be set at any angle with the aid of split balls; the specimen is supported on a swinging arm with its face horizontal. Of minor devices, we mention an improvement in the new moving coil reflecting galvanometer, for general use, weighing 6 lb.; the box containing the coil is pressed into the pole gap with a lead seal, and the screwed-in frame of the glass front of the box is also provided with a lead seal to keep out all dust. The totally suspended high-resistance indicator for thermo-couples, another novelty, is provided with a mechanical set-up device for the zero. The working range of these instruments lies generally between 500 deg. and 1,000 deg., but they are calibrated from 0 deg. upward. When one milled head is turned, the pointer is pushed up on a first scale; by turning a second milled head underneath the first the pointer is set back to 500 on a second scale. The dial thermometers for room and radiator temperatures consist of nickelled copper tubes, about finger size, filled with ether and connected by tubing of the same metal with the dial chamber. In the self-contained rotary bridge, a small square box, the bridge coils are wound in recesses in four ebonite drums, contact between the coils of adjacent drums being made by laminated copper brushes; balance is obtained by rotating the drums with the fingers; the ratio-coils giving multipliers of 0·1, 1, 10, are put in operation by pressing ivory keys. The cross-talk meter, finally to be noticed, is an instrument for measuring the amount of cross-talk going on between two telephone circuits. The two parts of the instrument are, first, a small box containing the pairs of terminals of the two lines to be examined, of a transmitter and receiver, &c., and a reversing switch (a push-over key), and secondly a circular low-resistance switch. By means of the reversing switch the telephone is connected in succession to the two lines and to the meter, and the resistance is adjusted in the circular switch until the sounds heard are equal for the two positions of the key.

The new Phantom wireless condenser of Messrs. Isenthal and Co., Denzil Works, Willesden, the invention of Mr. F. J. Chambers, is a variable condenser for radiotelegraphy calibrated in terms of wave-length. The instrument exhibited, of a maximum capacity of 2,500 microfarad, is a rectangular case of metal (the metal serves as electrostatic screen—maximum dimension about 6 in.) from the top of which two pairs of condensers A and B are suspended by flat strips which slide in two parallel longitudinal grooves of the top of the box; these grooves are calibrated in wave-lengths and electrostatic units respectively. Both condensers are built up of parallel plates in the usual fashion. The right-hand condenser of each pair is movable and earthed through the case; when it is approached to the left stationary condenser (which is insulated) and pushed into it, so that the plates alternate with one another, the capacity of the pair is varied. A is the main condenser and has many plates; the plates are square, but one corner of each plate is cut off diagonally; the capacity varies as the distance traversed, but there is leakage, to reduce which the plate area is large; the few plates of B are made extremely thin. The phantom condenser B is normally set to correspond with the absent area (of the corners cut off in A) and to correct for the leakage effect. When the instrument is joined to an oscillatory circuit, the phantom condenser is adjusted so as to compensate for the disturbance of the capacity by the coils of the circuit.

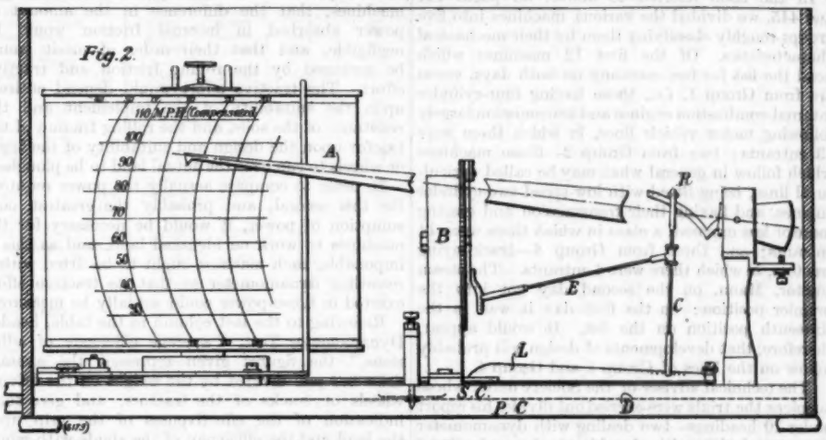
The 0·5-kw. and 1·5-kw. transformers, and the large induction coils (10-in. and 16-in. spark) of the High Tension Company, Belvedere-road, Westminster, are mainly for radiotelegraphy (portable sets) and for X-ray work.

The ends of the tubular resistances of the Zenith Manufacturing Company, of Willesden, N.W. 3, are fitted with ring castings so that the terminals can be tightened up without detriment to the tubes. The Zenith vibrating magnetic rectifier is a simple device for working from lamp sockets; the transformer coil is, at one end, encircled by a permanent magnet, between the poles of which a reed oscillates between carbon contacts; this reed serves as polarised relay, which gets into step with the alternations of the currents to be rectified. The resistance alloys used by the Concordia Electric Wire Company, who exhibited bare and covered wires, are nichrome, constantan (Cu-Ni), resistin (Mn-Cu), manganin (Cu-Mn-Ni), and vestalin (Ni-Fe).

The Stopford-Darling steel-hardening indicator, demonstrated by Messrs. A. Gallenkamp and Co., of 19, Sun-street, E.C. 2, is one of the instruments designed to mark the temperature at which the steel ceases to be magnetic and which is considered best for quenching the steel to be hardened. This object can be obtained, for instance, by placing a special coil round the circuit. Mr. C. R. Darling and

Mr. Stopford, of Finsbury Technical College, simply use a magnetic needle for closing a relay-circuit including a buzzer; the buzzer will sound when the temperature is reached, and the whole outfit required consists of a small box containing the magnet, which is bolted to any part of the furnace, and the buzzer.

A large number of captured German instruments were exhibited by the Air Ministry and—compasses especially—by the Admiralty Compass Observatory at Slough. There were stereotelescopes, range-finders, directors and sighting arcs, periscopes, clinometers, altimeters, petrol-level gauges, radiation thermometers, Telefunken generators, amplifiers, signalling lamps, respirators, &c.; many of these



are interesting on account their optical features and of their simple practical cases and clamping devices, &c., some also suggest the dearth of materials and the pressure of work. Several of these instruments were described last year in the Transactions of the Optical Society.

To our notices of optical instruments we have to add that Messrs. Ottway and Co. exhibited, in addition to theodolites, levels, mining dials, &c., a very simple focometer, of the measuring microscope type, a small dividing machine for graticules and Professor Dalby's gauge for measuring screw threads. Messrs. Henry Hughes and Son, of 59, Fenchurch-street, E.C. 3, and their agents, Messrs. S. Smith and Sons, of 179 to 185, Great Portland-street, had placed their aerial navigation instruments in a full-scale model of the cabin of the machine in which the illfated Captain Matthews attempted the flight to Australia. A special feature of this cabin is the Scarf ring on which azimuths and also positions can be taken, by means of land bearings. The machine carried three types of compasses, and two novelties, a Hughes-Baker air sextant and the Smith recording air-speed indicator.

The Baker air sextant, due to Commander Baker, R.A.F., looks more like a short periscope than a sextant. It consists of a vertical tube, which the aeronaut holds in his hand; one prism is mounted at the top, the other at the bottom, the eyepiece is in front of the latter, and a micrometer rod parallel to the tube. When the aeronaut is above the stratified clouds, unable to see the land or sea, he determines his horizon by taking the edge of a cloud as artificial horizon; looking into his air sextant he adjusts the micrometer until he sees the edge in front in alignment with the edge reflected from the back with the sun's image, where the two intersect. To facilitate taking observations in the glaring sun, a sunshade (a glass screen) is provided in front of the top prism. In the newest type of this sextant a bubble level is further mounted at the top of the tube, and this bubble is provided with a small lamp. The Smith recording air-speed indicator, the first instrument of this type, is compensated for altitude and air density, giving a record of the true air speeds and showing the landings, their time and duration; the instrument should be particularly useful for designers as well as for wind-channel experiments. As shown in our diagram, Fig. 2, (which is one-third full size) the barograph box is provided with a double bottom, a diaphragm D of a dense silk fabric separating the pressure chamber P.C. from the static chamber S.C. When the air pressure raises the diaphragm, it raises also the long steel spring L and the connecting rod C, which checks the movement of the pen arm A; the latter is pulled up by a spring (not shown), but held down by the little roller R which rides on a steel arc projecting from the pen arm. The speed thus indicated by the pen on the chart, which is clock-driven and calibrated in miles per hour, would not be compensated for the diminished air density at high altitudes. The compensation is obtained with the aid of the compensating box B, which is an aneroid box, but filled with air at normal pressure and temperature. As the atmosphere becomes rarefied, the box bulges out, and the rod E tilts the rod C, with which it is connected by a universal joint. The instrument, which is patented, was designed in the aerial department of Messrs. S. Smith and Son, which is under the management of Lieut. A. W. Hulbert, R.A.F., and was calibrated in the wind channel of the National Physical Laboratory; it weighs 8 lb.

We should not omit to mention that Messrs. Henry Hughes and Son have recently taken up the manufacture of standard drawing instruments by repetition machinery. A number of sets of instruments bearing the "Husun" trademark of the firm, were among the exhibits.

NOTES.

Surges in the Panama Canal.

On account of the large size of the locks on the Panama Canal, some data recently published in the *Canal Record*, dealing with surges set up in the canal during lockage operations, are of interest. The locks at Gatun and at Miraflores are supplied from comparatively large bodies of lake water. The locks at Pedro Miguel, on the other hand, draw their supply from the larger Gatun lake, through the famous Culebra Cut, which is about 8 miles in length. The theoretical dimensions of the canal for this portion are 300 ft. width by 45 ft. depth of water. In many places these dimensions have been exceeded on account of the removal of slides. Near the locks, in order to reduce the velocity of flow, the width has been increased to 600 ft., tapering gradually to 300 ft. The filling of one lock chamber requires 3,800,000 cub. ft. of water, and the lock takes 7½ minutes to fill with two culverts in use, or 13½ minutes with one in service. In the first case, the rate is 13,130 c.f.s., which is equivalent to a flow of 0·6 knots in the supply channel. This flow is not uniform. When the valves are opened, the water close to the locks falls with all valves in use as much as 18 in., and when shut, a surge is set up which has a crest 18 in. above mean lake level. This travels back up the cut and is felt 7½ miles up the tortuous former valley of the Chagres River and in a direction at right angles to the canal. These surges are also noticed 6 miles distant from Gamboa on the axis of the canal. The effect of opening the valves at Pedro Miguel is felt at Gatuncillo, 7½ miles from Gamboa up the Chagres, 78 minutes later. The effect of closing appears at the same place 82 minutes later. The peak of the return surge is felt at this point, 87 minutes after the time of high peak at Pedro Miguel. The three intervals for Gamboa, which is at the end of the long cut, are respectively 18, 19 and 25 minutes. The heights of the return surge at Gamboa is about one-eighth that of the peak at Pedro Miguel. The currents are not strong enough to affect navigation with ordinary precautions, though if the passage were restricted by wreck or slide in the cut, it would be unsafe to fill the lock quickly. The lock gates and walls, &c., at Pedro Miguel are high enough to prevent spilling over.

Improvements in Tea Machinery.

The position of engineer on a tea garden is not an altogether enviable one, as the pay, generally, is poor, and it very seldom leads to anything. To this fact is said to be due the relatively small improvement shown in tea machinery; those who might, in time, evolve changes as a result of practical working often leave the calling before their interest has been properly aroused. As a result, the design of such machinery is left to manufacturers who under difficult circumstances make an exceedingly good job of interpreting problems in which greater first-hand experience would probably carry them much further. In a paper read some time ago at Dibrugarh, Assam, before the Assam Section of the Junior Institution of Engineers, by Mr. C. M. Patterson, the authors draw attention to a design of drying machines in which, he says, the coal used is very largely employed merely in heating up the factories. He points out that, in the first place, the heater pipes from the stove are usually exposed and that the stove back plates, usually in a state of red heat, are exposed. The air duct leading from the stove to the drying chamber is also exposed. The drying chamber casing, further, is unprotected. The total surface of $\frac{1}{4}$th iron plating exposed in this machine is calculated by the author to be about 1,150 sq. ft. Obviously this results in an enormous amount of waste heat, and economy in this direction might well receive the attention of the manufacturers. The saving effected would soon pay for some extra initial cost of improved apparatus.

Connecting-Rod Bolts for Diesel Engines.

From the discussion at a recent meeting of the Diesel Engine Users' Association it would seem that there is as yet no settled practice as to the best material to employ for the bolts of connecting rods for Diesel engines. Some firms employ for this purpose Low Moor or Farnley iron, whilst others adopt 3 per cent. nickel steel, being able to reduce somewhat the dimensions of the big-end. Some builders advised that the bolts should be annealed yearly, whilst others consider this practice either unnecessary or detrimental. Experience seems to vary greatly as to the frequency with which these bolts break. Engineer-Commander, Church states that with the high-speed Diesel engines used for submarines failures are practically unknown. Only two failures have occurred, and in each case this was due to the slacking back of the bolts. The material which has been adopted for the connecting-rod bolts of these submarine engines has been a high grade acid steel, with a tensile strength of 28 to 32, or from 31 tons to 35 tons per square inch, and and one in eight of the finished bolts is tested to destruction. For 4-cycle engines running at 380 r.p.m. and developing 100 h.p. in each cylinder, the bolts have a diameter of 1¾ in., and the calculated stress on them is 6,600 lb. per square inch. In more recent engines, running at 400 r.p.m., 3 per cent. nickel steel has been used, having an ultimate strength of 40 tons to 45 tons per square inch. The material is "normalised," but not subjected to any special heat treatment. The bolts are designed so as to have ample "stretching" lengths with a diameter equal to that at the bottom of the thread, and an ample radius is provided at the bolt-head. Great care is taken in fitting to ensure that the brasses and liners are surfaced and abut properly. It is not the practice in the Navy to anneal the bolts periodically, and Commander Church concludes that

unless the initial design is at fault, there should be no danger of bolts failing from fatigue. Several of those who took part in the discussion held that in the case of a piston seizure the bolts should be entirely replaced by new ones.

OIL PROSPECTS IN SCOTLAND.

In a paper recently read before the Mining Institute of Scotland, Mr. H. M. Cadell gave reasons for believing that there is little prospect of finding any large beds of oil-bearing sands or rocks in Scotland. In his view, mineral oils are the consequence of a decomposition by natural processes of shales resembling those now worked in Scotland for paraffin and ammonia. These shales were deposited in land-locked bodies of water in the form of fine mud heavily impregnated with impalpable peaty particles, which later on formed the kerogen now found present in the shales. Under gentle heat this kerogen decomposed, yielding oil. Where this decomposition is effected by natural agencies, the oil gravitates away, and may be absorbed by porous beds of sandstone or limestone, overlying impervious strata. These, if subsequently tapped, may yield mineral oil. A study of the geological structure of Scotland leads him, however, to believe that the conditions there are not such as to render it likely that any large quantity of oil has in this region been entrapped in this manner. Small supplies may, no doubt, be met with, but the prospect of any large supply appears unlikely, an opinion which was endorsed by most of the other speakers who took part in the discussion. Scotch oil will thus, he holds, continue to be derived mainly from distillation of the shales, provided always that economic conditions do not make the continuation of the industry impossible. Were it not for the yield of ammonia simultaneously obtained, the distillation of these shales would have been abandoned years ago. The maintenance of the industry up to the present has, Mr. Cadell stated, been rendered possible only by the inventive genius of such men as Young, Henderson, Beilby and Fraser, who devised methods for extracting profitably all the products that could be squeezed from the shale. The speaker suggested that similar ability applied to the distillation of peat might result in a considerable increase in the total output of Scotch oils. Here, again, it is the large ammonia content that may make the operation commercially feasible. At the outset only the richer deposits could be treated, but some of these contain nearly 2½ per cent. of nitrogen, and a yield of 180 lb. of ammonia sulphate per ton of peat should be practically attainable. In view of the high value of ammonia sulphate, the oil simultaneously obtained from the peat would be more or less of a by-product. At the same time, there should be a substantial yield of acetone, alcohol and paraffin-wax. Hence, in considering Scottish oil possibilities, Mr. Cadell thinks special attention should be given to the practicability of utilising the peat mosses.

BOARD OF TRADE BRANCH OFFICES.—The War Insurance Accounts Branch of the Board of Trade and the headquarters of the Statistical Department have now removed from Gwydyr House Annexe, Whitehall, to the Board of Trade Offices in Great George-street, Westminster, S.W. 1.

AMERICAN PLANS IN BRITISH INDIA.—There are rumours, says *The Board of Trade Journal*, of the probable early appointment of a permanent Trade Commissioner in India by the United States Government, although so far the American Consulate in Calcutta is without definite news on the subject. In this connection, however, it is of interest to observe that Mr. W. H. Rastall is now visiting India as a Special Trade Commissioner of the United States Government to investigate the prospects for the extension of the sale of American machinery. Mr. Rastall is a mechanical engineer, who during the war was in charge, in Washington, of the aircraft productions of two of the American States, and he was despatched on this special mission to the East just before the armistice was signed. He came to India *via* Java and the Straits Settlements, and proposes to stay four months, then proceeding to China and the Far East. Up to the present with the exception of the American Consular Officers in Calcutta and Bombay, virtually no commercial work has been conducted on behalf of the United States Government in India, but this mission and the probability of the appointment of a permanent Trade Commissioner would seem to indicate a determination to foster trade officially, and to presage still keener American competition in the Indian markets.

THE LINCOLN TRACTOR TRIALS.

THE judges have now issued their report on the result of the tractor trials held at Lincoln from September 24 to 27. This is bound in book form, and can be obtained by those interested from the Society of Motor Manufacturers and Traders (price 5*s.*). The report is very complete in regard to the statistics and data of each of the tractors; it also gives a photograph of each machine, together with a short description of its mechanical specification. Most of these data we have already published in our issue of October 3, 1919, and the table we now publish on the opposite page gives a summary of the results.

In the issue referred to above, on pages 444 and 445, we divided the various machines into five groups roughly classifying them by their mechanical characteristics. Of the first 12 machines which head the list for fuel economy on both days, seven are from Group 1, *i.e.*, those having four-cylinder internal-combustion engines and transmission largely following motor vehicle lines, in which there were 13 entrants; two from Group 2—those machines which follow in general what may be called agricultural lines, being fitted with low-speed two-cylinder engines, and having their transmission and gearing more or less exposed, a class in which there were 14 entrants; and three from Group 4—track-laying tractors, in which there were 4 entrants. The steam tractor, Mann, on the second day got into the premier position; on the first day it was in the sixteenth position on the list. It would appear, therefore, that developments of design will probably follow on the lines of Group 1 and Group 4.

The technical adviser of the Society under whose auspices the trials were carried out divides his report under 10 headings—two dealing with dynamometer tests, two dealing with ploughing on heavy land and cliff land, two with haulage and threshing, whilst one section deals with the mechanical construction, another with the safety, one with the results of oil tests, and finally his report concludes with a brief description of each make and type of tractor engaged. A graph of the dynamometer record in each case is given, and these are very interesting, and form a useful record of the performances. The rules provide for no award or prize, but various figures of merit have been given for—

1. Relative capacity in acres per hour.
2. Fuel cost per acre.
3. Fuel cost per 100 lb. of draw-bar pull on plough.

Two sets of tables giving these figures for the two days' ploughing are published, and we have collected these figures together in order that the ploughing on heavy land and the ploughing on light land may be more readily compared. It will be noticed that there is a great disparity between the performance of the same tractor on the two days, and one which calls attention to the fact that the order of merit given in these six tables cannot, without qualification, be taken at its face value as to the relative merits of the various machines. No doubt every care has been taken in organising the trial to rule out as many variants as possible in order that such a comparison may be made, and with this end in view the dynamometer test has been made with a plough in the different fields and the result recorded. These results show the amount of pull required to propel a particular plough at that time, but as the fields were very large, and in some cases furrows were half a mile long, and different machines used different boards, there is not the slightest doubt that they are not adequately representative of the average tractive effort required throughout the day.

Many of the competitors were seriously handicapped by the extreme difficulties of transit and labour conditions at the time the trials were conducted, these having taken place just the week before the railway strike. Some machines did not arrive on the ground until late the night before, and had no opportunity to make their final adjustments to suit the land they were about to plough. Also, some competitors had to be content to use such ploughs as they were able to obtain, and these were not always suited to the land. So much was this the case that the judges called attention to the point in their report.

Then it should be taken into consideration that in providing land for such a large number of machines (more than 500 acres were ploughed in the two days) it was impossible to arrange that it should be all exactly alike in regard to the power to pull and shape of plough required to work it.

In mechanical ploughing the power consumed may be roughly divided under three heads:—

1. On overcoming internal friction and gearing of the machinery.
2. Overcoming the rolling friction of the tractor over the ground.
3. Providing draw-bar pull to drag the implement.

It is probable among, say, the first 12 to 16 machines, that the difference in the amount of power absorbed in internal friction would be negligible, and that their order of merit would be arranged by the rolling friction and tractive effort. The tractive effort would depend entirely upon the suitability of the implement and the resistance of the soils, and the rolling friction of the tractor upon the design and suitability of the track or wheels to run over the actual land to be ploughed.

In order to compare actually the power required for this second, and probably the greatest, consumption of power, it would be necessary for the machines to work on identical land, and as this is impossible, each machine ought to be fitted with a recording dynamometer so that its tractive effort exerted in horse-power could actually be measured.

Referring to the last column in the table, headed Dynamometer Test, "average efficiency of adhesions," the figures given represent the average draw-bar pull divided by the weight on the driving wheels or tracks of the tractors, and give some indication of the effectiveness of the grip upon the land and the efficiency of the spuds with which the driving wheels or tracks were fitted. This, of course, can be readily varied by a change of spuds. The test was only instituted to enable competitors to ascertain the effectiveness of such devices upon the land about to be ploughed, and really does not, without comment, form a relative characteristic of the design. For instance, the Cleveland tractor—which was tested without any spuds or projections of any kind, and therefore shows a very low efficiency, to which the technical adviser calls attention.

Each competitor was informed of the average pull exerted by his tractor up to the point at which the driving wheel began to slip, and this enabled him to arrange his spuds and choose the number of plough breasts that he would use.

On Wednesday's ploughing the measurement of resistance to plough the heavy land gave the result that it required from 9·85 lb. to 12·3 lb. per square inch of the cross-section disturbed, and on Thursday's ploughing on the light land the resistance varied from 7·91 lb. to 11·40 lb. per square inch, thus showing that some of the light land was actually stronger than the heavy. It was also a matter of comment in the judges' report that many of the ploughs did not maintain their proper depth and that good work was sacrificed to speed.

If it had been possible to use a recording dynamometer on the draw-bar of each machine, the temptation to do this would have been less and a truer result would have been obtained of the actual fuel economy of the implement and the tractor. The reason for the bad performance of the Mann steamer on the first day was undoubtedly due to the bad surface and local wetness at the bottom of the field, indeed one portion of it was actually standing under surface water, and no farmer would have ploughed land in this condition, especially as the adjoining field on the same farm was in perfect condition for working the soil. However, this condition of soil penalised the heavy machine, and probably rightly, and placed its order of merit below other machines that were competing. When, however, on the second day, it was at work upon a dry field with a good firm surface, it performed well, and stood out right at the head of the list for economy and speed.

In reviewing the performance of the first 12 machines we have tried to arrive at some basis or comparison between their relative performance on the two days. It is remarkable that the fuel consumption per acre of the three track machines was almost identical for the two days, although their

TABLE OF RESULTS OF TRACTOR TRIALS AT LINCOLN.

Name of Competitor.	Dynamometer Tests. Pull to Skid Tractor Wheel.	Sustained Pull at Ploughing Speed.	Drawbar Horse-Power as shown by Test.	Efficiency of Adhesion	Result of Ploughing on Heavy Land. Acres per Hour. Capacity.	Order of Merit.	Fuel Cost. Per Acre.	Order of Merit.	Per 100 Lb. of Drawbar Pull.	Order of Merit.	Results of Ploughing on Light and Medium Land. Acres per Hour. Capacity.	Order of Merit.	Fuel Cost. Per Acre.	Order of Merit.	Per 100 Lb. of Drawbar Pull.	Order of Merit.
	lb.	lb.		per cent.			s. d.		d.				s. d.		d.	
Alldays	4,100	3,300	15	74	0·57	18	5 8	20	2·52	5	—	—	—	—	—	—
Austin	2,900	1,950	8½	85	0·62	14	4 5	12	2·68	7	—	—	3 1	4	2·78	8
Austin	—	—	—	—	0·66	9	4 7	13	2·78	8	0·79	9	2 10	3	2·54	6
Avery	4,300	3,800	12½	68	0·73	6	4 8	14	2·92	12	0·90	3	4 4	21	2·92	9
Blackstone Track ..	3,100	2,300	10½	46	0·69	7	3 0	1	1·98	3	0·64	22	3 5	8	2·42	5
Clayton Track ..	4,750	3,500	13½	56	0·81	2	3 7	2	1·70	1	0·81	8	3 8	13	1·86	2
Cleveland Track ..	2,300	1,650	10	52	0·63	10	3 10	5	2·88	11	0·54	31	4 4	22	3·82	25
Cleveland Track ..	—	—	—	—	—	—	—	—	—	—	0·71	16	3 11	18	3·50	21
Crawley .. (p)	3,100	2,300	12½	50	0·67	8	8 0	30	4·84	26	0·72	15	5 8	31	4·2	29
Emerson	4,000	3,000	14½	90	0·57	19	4 2	9	2·62	6	0·67	20	3 3	6	2·74	7
Eros .. .. (p)	2,100	1,500	8½	94	0·53	23	6 2	22	5·96	30	0·49	33	6 0	35	6·60	34
Fiat	5,300	3,550	12	89	0·87	1	3 10	6	2·80	9	0·93	2	2 5	1	1·94	4
Fordson	2,200	1,500	6½	83	0·43	27	6 2	23	6·72	32	0·78	12	3 10	15	4·64	31
Fordson	—	—	—	—	0·54	33	4 3	10	3·86	22	0·61	25	3 7	12	4·80	32
Garner	2,300	1,900	14	70	0·48	25	7 0	27	5·70	29	0·87	4	4 5	28	3·48	20
Garner	—	—	—	—	—	—	—	—	—	—	0·78	11	—	—	—	—
G. O.	2,300	1,900	8	68	0·38	31	5 2	17	2·92	13	0·55	30	4 0	17	3·22	17
Glasgow .. (p)	3,550	2,800	13	65	0·54	22	12 0	33	6·76	33	0·70	17	6 4	36	4·24	30
Gray .. .. (p)	4,500	3,800	14½	76	0·80	3	10 2	32	4·28	25	0·86	5	5 10	32	3·52	22
Illinois	—	—	—	—	0·32	34	8 11	31	5·00	27	0·79	10	3 8	14	3·24	15
Mogul	5,000	4,200	19	53	0·61	15	6 8	26	3·14	16	0·70	18	4 5	24	3·18	15
International Junior	2,600	2,150	11½	83	0·43	28	4 4	11	3·84	21	0·64	23	3 5½	11	3 18	16
Titan	4,200	2,900	14½	58	0·57	20	4 0	8	3·94	23	0·52	32	4 3	20	3·80	26
Titan	—	—	—	—	0·55	21	5 2	18	3·80	20	0·68	19	3 4	7	3·06	12
Mann Steamer (c)	6,000	4,700	22	67	0·59	16	6 4	24	3·10	15	1·08	1	2 9	2	1·50	1
Martin Track ..	2,500	2,050	11	46	0·42	29	7 6	28	4·26	24	0·42	36	4 8	25	4·10	28
Martin Wheel ..	3,300	2,700	14½	77	0·63	11	5 10	21	3·30	19	0·60	29	4 2	19	3·40	19
Maskell	—	—	—	—	—	—	—	—	—	—	0·46	35	5 5	28	6·60	35
Moline	2,000	1,600	9½	47	0·47	26	12 6	34	7·60	34	0·75	13	5 2	26	4·08	27
Moline .. (p)	—	—	—	—	—	—	—	—	—	—	0·48	34	5 6	29	4·80	33
Omnitractor ..	4,100	3,200	17	58	0·38	32	5 2	19	2·82	10	0·84	6	5 10	33	3·52	26
Overtime	3,800	3,200	15	80	0·75	4	3 9	4	1·80	2	0·65	21	4 0	18	2·36	4
Pick	2,500	1,800	8	53	—	—	—	—	—	—	0·61	26	8 4	37	7·44	37
Saunderson	3,000	2,700	9½	59	0·49	24	7 8	29	6·20	31	0·63	24	5 7	30	3·04	11
Saunderson	—	—	—	—	0·74	5	5 0	16	2·98	14	0·83	7	5 3	27	3·80	24
Wallis Junior ..	2,600	2,800	12½	80	0·63	12	3 11	7	3·15	17	0·75	14	3 1	5	3·14	13
Wallis Junior ..	—	—	—	—	0·63	13	4 11	15	3·28	18	0·61	27	3 5	9	3·14	14
Weeks Simplex ..	2,900	2,250	9	83	0·59	17	3 8	3	2·46	4	0·61	28	3 5	10	3·00	10
Whiting Bull ..	2,300	1,700	7	53	0·41	30	6 5	25	5·66	28	0·40	37	5 10	34	6·96	36

(p) = Petrol. (c) = Coal.

draw-bar pull varied considerably. It would thus appear that the track machine with its low intensity of pressure upon the soil shows up to greater advantage on heavy slippery ground than on dry light ground, and that the other wheel machines practically group themselves in efficiency in more or less proportion to their weight per square inch carried on their contact with the ground. It is also remarkable that the Little Eros tractor, which only consists of a pair of ordinary shafting pulleys put on to the back of a Ford car, was able, with its 1,600 lb. weight upon the driving wheels, to maintain a draw-bar pull of 8½ h.p., when some of the other and larger machines with 2,400 lb. on the driving wheels maintained less than this amount. This clearly demonstrates that large weights are not necessary to provide tractive effort, and that with suitable spuds light tractors will be successful.

The performance of the self-contained machines is disappointing, as regards petrol consumption, and, as previously pointed out, the results are probably deceptive. The extreme facility with which they can be steered assures for them a great future in tilling and cultivating ground among fruit trees, orchards and plantations where a tractor pulling a separate plough cannot compete. Taken generally the impression we have gained from our attendance through the whole week of the trials is that a great work has been done which will be very useful indeed to those who were on the ground and saw the actual performances of the various machines. Those who followed the work with the aid of these figures will be able accurately to judge of the respective fitness of the machines for their particular work.

There is no doubt that these trials have proved what has been well known to those concerned, that the design of the plough boards will have to be considerably modified, as the economical speed of mechanical traction is more than double that of the horse, and plough boards will have to be developed which will perform the work at a greater speed and equal excellence.

At the end of the trials a sample of lubricating oil was taken from every engine, and the tests failed to give any evidence of a serious leakage of paraffin past the piston rings, or any serious contamination of the oil arising from faulty construction of the engine, thus demonstratnig that considerable advance has been made in paraffin carburettor design.

Scientific tests of the various machines, when used for driving a threshing drum, were given up, as the time was too short, but all that entered showed their capacity to drive satisfactorily a 4-ft. 6-in. threshing machine under average conditions.

In the haulage tests, which were conducted over a steep hill of an average gradient of approximately 1 in 11, with a short piece of 1 in 9, the eleven competitors who took part demonstrated their ability to pull a load of 4 tons up this gradient when the wheels were shod with suitable tyres. The road surface at the time was good and dry, and some tractors took their load with ordinary steel tyres fitted with diagonal strakes, as is usual in tractor engine practice, while others were shod with rubber. It was noticeable, however, that the rubber tyre was really the only efficient shoe for a tractor wheel working under these conditions, as, although the steel shod wheels surmounted the hill, a considerable amount of slipping was observed on the steep portions and had the surface been wet the engines would have been unable to perform the test.

In the judges' opinion, the short time occupied by the trials was not sufficient for any definite opinion to be given on the reliability of any machine, but the tractors ran singularly free from mechanical trouble. The judges lay stress upon the necessity for simple construction, because the machines have mostly to be worked by men who have little or no mechanical knowledge, and are always at a great distance from any mechanical help. Strength is very important, both in build and engine power, and they recommend a large reserve, so that any sudden strains or jerks may not injure the machine. Great importance is attached to the point that all the working parts should be properly enclosed. The judges were of the opinion that there is room for further investigation and design to improve the wearing capacity of the caterpillar tractor tracks as these have such marked advantages on particular classes of land. If proper protection and suitable lubrication could be provided to ensure a long life, these machines would have a very wide field for employment.

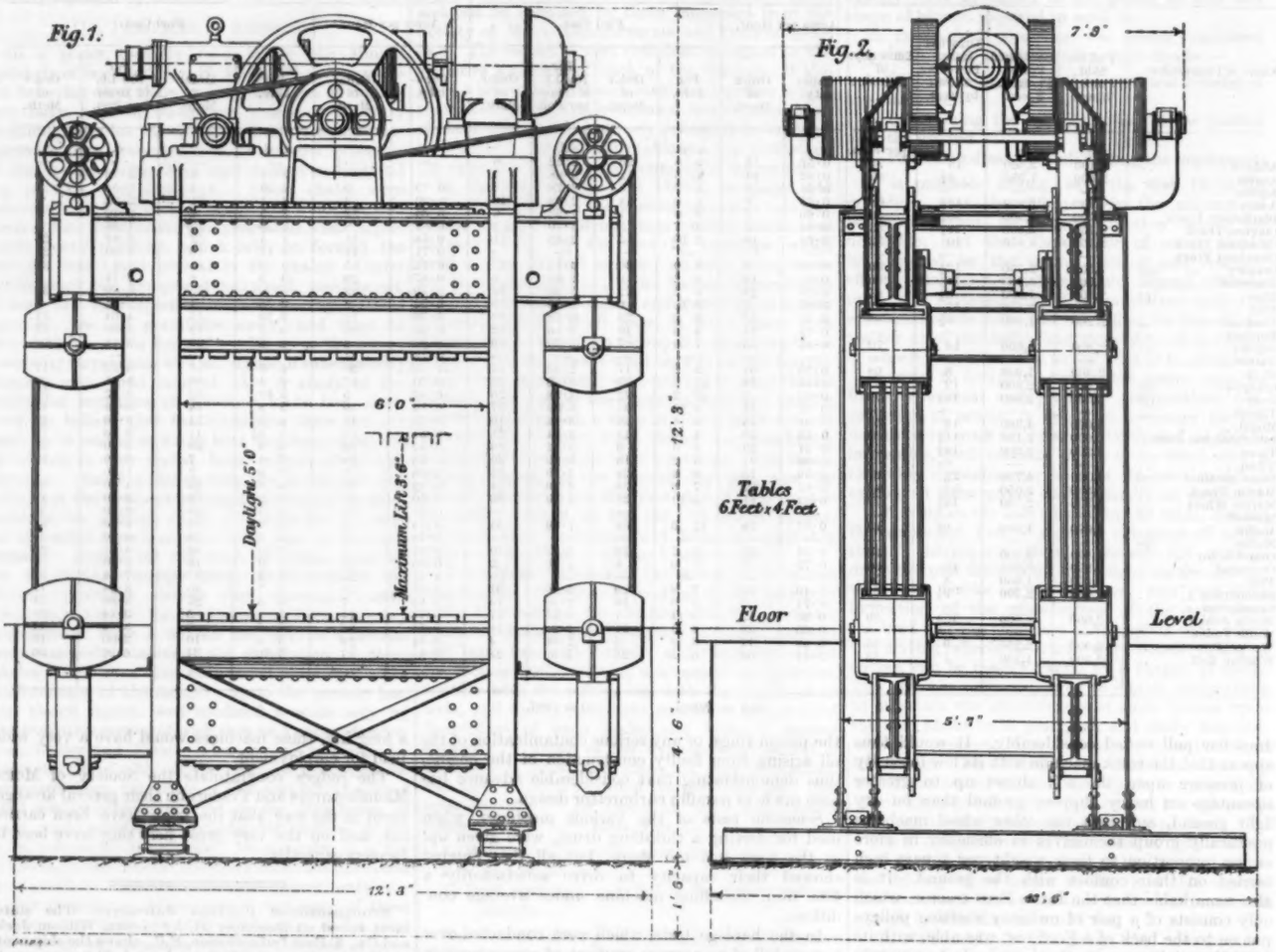
The judges congratulate the Society of Motor Manufacturers and Traders on their general arrangement in the way that the trials have been carried out, and on the very great help they have been to farmers generally.

MIDDLESBROUGH PIG-IRON SHIPMENTS.—The statement issued on December 31, by Messrs. William Jacks and Co., 5, East India-avenue, E.C., shows the shipments of pig-iron from Middlesbrough and Skinningrove to have been in December, 5,710 tons coastwise and 20,862 tons foreign, a total of 35,572 tons, as compared with 24,473 tons in November last, 28,513 tons in December, 1918, and 27,720 tons in December, 1917.

ELECTRIC WINDING PLANT IN NORTHUMBERLAND.—An electric main winding gear has recently been put into service at the Isabella Colliery of the Cowpen Coal Company, of Blythe, Northumberland. The electrical part of the gear was supplied by the A.E.G. Electrical Company, Ltd., and the erection was completed in August, 1914, but owing to war conditions it was not considered desirable to put the plant into commission until November last. The mechanical part of the winding gear was supplied by Messrs. Douglas and Grant of Kirkcaldy, and the steel pulley framing and structural work was carried out by Messrs. Joseph Cook, Sons and Co., Limited, of Washington, Co. Durham. The electric winder replaces a vertical, condensing, steam winder which was built by Messrs. Thomas Murray, of Chester-le-Street, seventy years ago. The power supply is taken from the mains of the Northern Counties Electricity Supply Company, in the form of 3-phase, 40-cycle, 2750 volt current, and the gear is required to raise 150 tons an hour from a vertical depth of 900 ft. The present output is 120 tons an hour. The gear is of the Ward-Leonard type, the converting set consisting of a three-bearing unit with an output of 445 kw. Ultimately this is to be increased to 550 kw. by the fitting of a larger driving motor. The winding motor is of the open ventilated type and the present speed is 59 r.p.m. Ultimately this will be raised to 70 r.p.m. A Kapp phase-compensator of Messrs. Sandycroft's make works in conjunction with the motor and Ward-Leonard set. The main brakes are of the post type, applied by means of weights and held off by compressed air, which is supplied either from a self-contained electrically driven compressor forming part of the plant, or from the main pit supply. Electrical or mechanical appliances are fitted to stop the motor and apply the brakes in case of failure of supply, or of failure of the existing current, or fall of the air pressure below 50 lb. A limit switch is also fixed to prevent the cage being lifted more than 3 ft. above the kops.

200-TON ELECTRIC BALING PRESS.

CONSTRUCTED BY MESSRS. HINDLE, SON AND CO., ENGINEERS, HASLINGDEN, LANCS.



WITH freight as high as it is at present, it is of the utmost importance that all goods which lend themselves to the treatment without harm should be properly baled. Where such power is available electric baling presses present many good points, as for instance, rapidity of operation, low cost of maintenance, &c. A 200-ton press of this class which is illustrated on this and the opposite pages, was designed and built for the South Indian Export Company, Bombay, by Messrs. Hindle, Son and Co., Union Engineering Works, Haslingden, Lancs.

The total nominal pressure exerted by this press is 200 tons. It is worked by a series wound motor capable of a peak output of 30 brake horse-power at 230 r.p.m., and accelerating on light loads and when lowering to 1,200 r.p.m. From our illustrations it will be seen that the frame consists of rolled steel sections and plates. This frame does not take the stress exerted as in the hydraulic press, but merely supports the table, machinery, &c. The whole of the machinery, motor, gearing, winding drums and brake are arranged on a casting on the top of the press framework. The table is raised by ropes and blocks at each corner, the ropes being 3-in. specially flexible steel cables, and the pulley ratios being 10 to 1. The load is distributed between 40 ropes giving a load per rope of 5 tons. The rope from each corner is led up and wound on two parallel winding drums, driven by the motor by worm and spur gearing. The drums are grooved. Equalising pulleys are provided by which the table may be levelled and the ropes adjusted, after which the latter are fixed by strong clamps mounted on the top table girders.

The motor runs in one direction for raising and is reversed for lowering the press table. The pressure exerted can be maintained for an indefinite period by means of an electromagnetic disc brake on the motor shaft. The current taken from the mains is proportional to the work done; when it has increased to a maximum the motor is stopped automatically. The automatic speed variation of the series motor allows the press to travel very quickly when running light or lowering. The motor is provided with ball bearings and is particularly designed for high speeds on light load, thus making the working of the press extremely rapid. The control is by push buttons, for "up," "down" and "stop." These operate contactor switches in the controller. The press table operates an auxiliary current switch at the top and bottom limits of its travel, thus preventing overwinding. A maximum current trip-switch is also incorporated in the controller, which acts on a predetermined current being reached. This stops the motor when full pressure is obtained, regardless of the kind of material, or size of bale in the press.

The tables of the press are 6 ft. by 4 ft., and the clear height between the tables is 5 ft. On test the time taken to compress a bale of jute bags measuring 5 ft. free, to 2 ft. in height, was 26 seconds. Lowering out occupied 36 seconds. The maximum current on a 440-volt circuit direct current was 60 amperes, the current consumed being about $\frac{1}{4}$ unit per bale. The purchasers were represented during the construction and testing by Mr. J. Grice Stratton, M.I.E.E. It is intended for baling hides for export.

PRODUCER GAS FOR MOTOR VEHICLES.*

By D. J. SMITH, Member of Council.

(Concluded from page 64.)

The Design of Vehicles to use Producer Gas.—Producer gas as a fuel offers so many advantages that it is essential to consider the design of a vehicle to use this fuel, as if it is used in engines designed for petrol the best results cannot be obtained and its use is likely to prove disappointing. The petrol engine is designed to use a fuel which is relatively expensive, and every designer has made fuel economy his first thought.

While it is necessary to consider economy, even with producer gas, it is by no means such an important item as it is with petrol, and the advent of a cheap fuel serves, in the opinion of the author, as an opportunity to introduce a type midway between the present steam and petrol vehicles, having the low upkeep and reliability of the former with most of the advantages of the latter, such as large radius of action, &c., with a fuel cost only a fraction of that of either.

The chief alterations would be in the design of the engine, and the author proposes to deal with this only. Using a cheap fuel, the need for a small high-speed engine for commercial work vanishes to a large extent, and it is possible to consider a large comparatively slow-running engine having the long life and low upkeep cost of a stationary engine. The increase in weight would not be considerable, and it should be noted that the author in the comparison in running costs between petrol, steam and producer gas vehicles has allowed 10 cwt. for the increased weight of such a vehicle, including the producer. This increase would cover the weight of the larger engine also, but not of any increase in the strength of the other parts of the vehicle, as doubtless the widest application of producer gas would be to vehicles which may be termed medium-built commercial vehicles, and differing only from the present petrol lorries in having an engine designed to use this fuel.

An example of what the author has in mind in heavier vehicles is the action now being taken by a well-known firm, which is fitting the chassis of a steam lorry with a gas engine and his producer. This is a combination of well-tried and proved units, and the result of the assembly should prove very satisfactory and allow of heavy loads being conveyed at a lower cost than ever before on common roads with the disadvantages of short water range and heavy fuel consumption of the steam vehicle abolished. These are, however, matters for the designer to work out, but the engine details include no experimenting.

A higher compression, with a half-compression device, as used on many stationary engines and on some makes of petrol engines, is essential. A pressure of 120 lb. to 130 lb. by gauge would be necessary to obtain a fair economy with producer gas. An increase of 25 per cent. in cylinder dimensions with a reduction in speed to a maximum of, say, 700 r.p.m., would not add unduly to

* Paper read before the Institution of Automobile Engineers, January 7, 1920.

200-TON ELECTRIC BALING PRESS.

CONSTRUCTED BY MESSRS. HINDLE, SON AND CO., ENGINEERS, HASLINGDEN, LANCS.

(*For Description, see opposite Page.*)

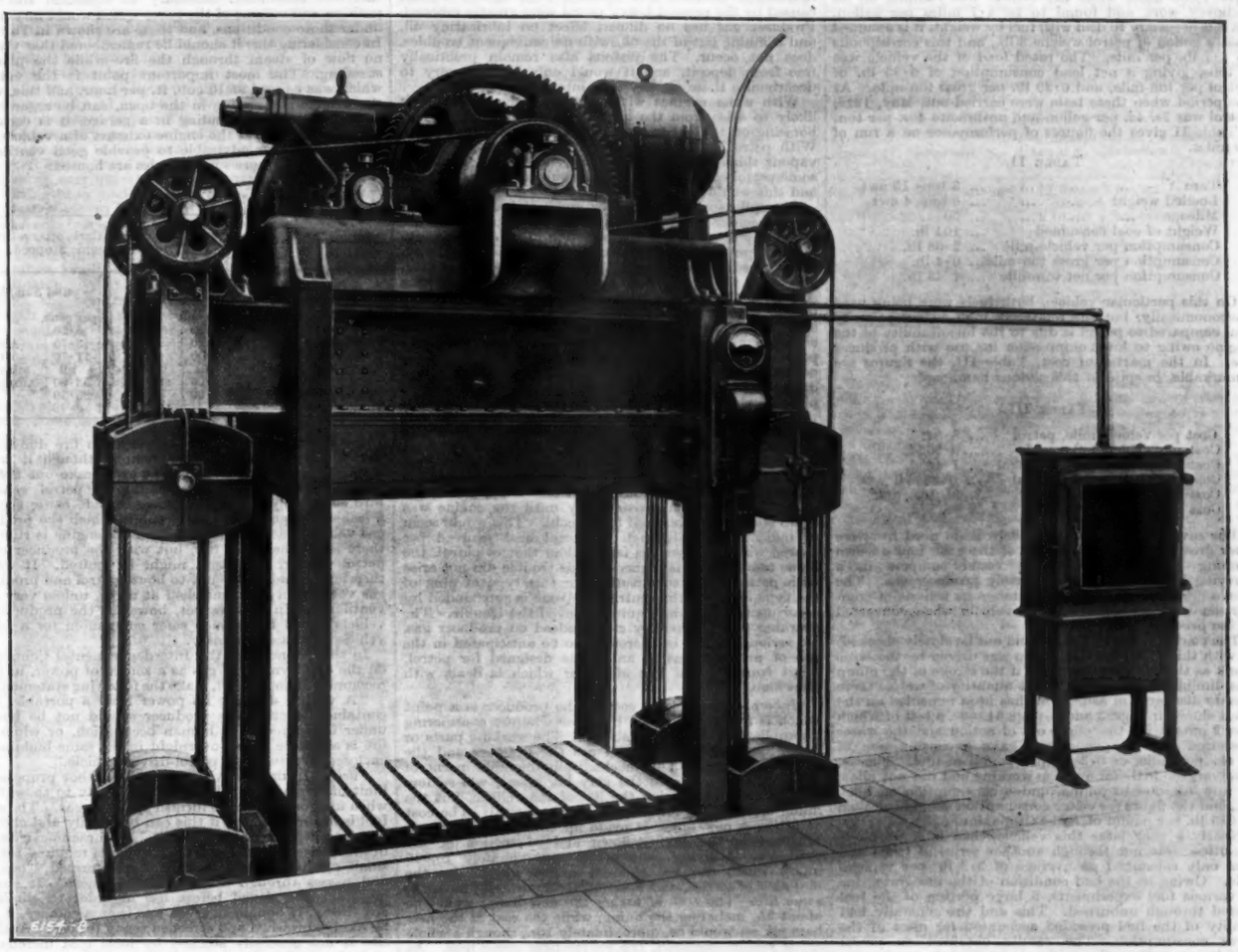


FIG. 3.

the weight of or space occupied by the engine, and should materially increase the life if the engine were substantially designed. The author has in mind a four-cylinder stationary engine, 6½ in. diameter by 7½ in. stroke, giving 43 brake horse-power on producer gas at 600 r.p.m. This engine ran over 15,000 hours without renewal of any working parts, and sometimes ran 144 hours without stopping. At 10 m.p.h. this would correspond to 150,000 miles. In the heavy slow-speed stationary engines, such records as the above are easily outdistanced, but this is not a type which could be used for vehicle work. The producer could be covered by the bonnet, the scrubber being situated behind the radiator with the fan in between. This would give a compact power plant and still allow of free access to the engine.

The use of the high compression necessary for producer gas renders the engine unsuitable for use with petrol, but the author does not consider this a serious drawback, as it is not likely that petrol would ever require to be used, as one at least of the fuels suitable for the producer would be obtainable practically everywhere and manufacturers would, no doubt, for vehicles up to 3 tons, adhere to a standard chassis and fit different engines according to the fuel to be used.

The Use of Producer Gas on Petrol Vehicles.—Owing to the very great saving possible in fuel cost by the use of producer gas, many existing petrol vehicles will no doubt be adapted for its use, and unless this is properly done, the results will be disappointing, if not absolutely unsatisfactory. It is no longer, as the author has demonstrated, a matter of doubt as to whether a producer can be so reduced in size and weight and suitably modified as to allow it to be used for vehicle work. To adapt it for use with an engine designed for quite a different fuel is another matter. With most makes and types of commercial vehicles the problem resolves itself into one of power, if gas from anthracite or coke is used. Alterations to engines are seldom satisfactory, and the author is chary of advising this course. Assuming, however, that no alteration in the engine is made, there is a loss of power of anything up to 20 per cent., varying with the design of engine, by using producer gas from anthracite or coke in place of petrol. With a high-powered vehicle having a relatively low gear ratio, this may not be serious, but with others, where the engine power is comparatively low in proportion to the gross load or the gear ratio is bad, it might be impossible to use producer gas if the vehicle had to perform the same work as on petrol.

An instance may be given of two vehicles of different make, both rated at the same carrying capacity, one having an engine of 108 mm. diameter by 150 mm. stroke and the other 150 mm. diameter by 160 mm. stroke, the gear ratios being almost identical. If the vehicle is chain driven, it may be possible to fit smaller pinions on the countershaft, and thus, to an extent, negative the loss in power, but at the sacrifice of speed. With vehicles having a bevel or worm-driven rear axle, no alteration is generally possible, so that the loss of power must be accepted unless some alteration can be made in the engine or gear-box. Some advantage would be obtained by increasing the compression, and a new set of dome-topped pistons is the best method of obtaining this. In some engines it is possible to fit new cylinders of larger bore, the compression being also increased. This is an expensive matter, and only possible in a few cases. A new and larger engine is the only remedy with many vehicles, as they are underpowered on petrol. This may seem a very expensive alternative, but it must be remembered that by the use of producer gas, it has been found possible to save over 30*l.* in fuel for 1,000 miles running, and at this rate a new engine would prove a very good investment.

With many makes, it is possible to instal producer gas without alteration and for the vehicle to perform its normal work with only a slight loss in speed over a give and take road, while in level districts producer gas could be used without any difficulty on any vehicle designed for petrol.

The author considers, however, that where it is intended to use producer gas on a petrol vehicle prepared peat should be used as fuel, reserving anthracite, coke and the more readily obtained fuels for vehicles designed for use with producer gas. The quantity of peat required is not large, and it would very soon be generally obtainable if a demand existed for it. In any case, no difficulty would be met with in getting stocks to be held at the vehicle garages, and as a supply for a 200 miles run can be readily carried, inability to get this on the road would not present a serious difficulty, especially as, in the case of a shortage, the vehicle could always be run on anthracite, coke or charcoal. Peat could, of course, be used for vehicles designed for producer gas, and if obtainable at the price quoted to the author, would be preferable, but the reason for advocating this fuel especially for vehicles designed to use petrol, will be made clear by the details given under "Fuels" in this paper, and by the fact that it almost entirely removes the difficulty of loss of power caused by using gas from anthracite and coke in a petrol engine.

The Performance of a Petrol Vehicle on Producer Gas.—The use of producer gas derived from anthracite or coke on a petrol vehicle without any alteration in the engine or the gear ratio could hardly be expected to give satisfactory results, yet the following details show that it is possible for the vehicle to put up quite a good performance, and the saving in cost of fuel would more than counterbalance any drawbacks due to the use of producer gas.

The vehicle in question was fitted with a four-cylinder engine, 4½ in. diameter by 5 in. stroke, and, owing either to wear or design, the gauge compression pressure was only 65 lb. per square inch. Four speeds were fitted and the final drive was by worm, making any alteration

in the gear ratio impossible. The weight of the vehicle fitted for petrol was 3 tons 12 cwt. 3 qrs. The carburettor and its connections were removed and the producer plant fitted, bringing the weight up to 3 tons 15 cwt. The vehicle had been "cast" or discarded for service, and was in need of thorough overhaul, but no work of any sort, apart from the fitting of the producer, was carried out.

The petrol consumption had been officially checked for over 1,000 miles while the vehicle was running on its ordinary work and found to be 4·7 miles per gallon. As it is necessary to deal with fuel by weight, it is assumed that a gallon of petrol weighs 8 lb., and this corresponds to 1·7 lb. per mile. The rated load of the vehicle was 2 tons, giving a net load consumption of 0·85 lb. of petrol per ton-mile, and 0·29 lb. per gross ton-mile. At the period when these tests were carried out, May, 1918, petrol was 3*s.* 4*d.* per gallon and anthracite 40*s.* per ton.

Table II gives the figures of performance on a run of 50 miles.

TABLE II.

Tare	... 3 tons 15 cwt.
Loaded weight	... 5 tons 4 cwt.
Mileage	... 50
Weight of coal consumed	... 104 lb.
Consumption per vehicle-mile	... 2·08 lb.
Consumption per gross ton-mile...	0·4 lb.
Consumption per net ton-mile	... 1·43 lb.

On this particular vehicle, both fuels were being used uneconomically, but the relatively high consumption of coal compared to petrol is due to the unsuitability of the engine owing to low compression for use with producer gas. In the matter of cost, Table III, the figures are remarkable, in spite of this serious handicap.

TABLE III.

Cost per vehicle-mile, petrol	... 8·5*d.*
Cost per vehicle-mile, coal	... 0·566*d.*
Cost per gross ton-mile, petrol	... 1·450*d.*
Cost per gross ton-mile, coal	... 0·0856*d.*
Cost per 100 miles, petrol	... 3*l.* 10*s.* 10*d.*
Cost per 100 miles, coal ...	... 4*s.* 8½*d.*

The saving is so great that there is no need to strive after great economy in the use of the coal, and no firm running petrol-driven vehicles could compete in a carrying business with a firm using producer gas. The above figures, however, can be taken as a basis of comparison with any petrol-driven vehicle when converted to use producer gas.

The consumption of water could not be closely checked, as with this plant the feed pump was driven by the same crank as the ash discharge, and if the stroke of the pump was diminished to give the right quantity of water, there was no discharge of ash. This has been remedied on the plant shown in Figs. 3 and 4, page 61 *ante*, a test of which over 2 miles with the pump out of action and the water measured into the vaporiser, gave a consumption of 10 oz. per mile, or 0·3 lb. per pound of fuel. This is, however, too little for average working and did not allow for any loss due to rolling, undue consumption on hills, &c., and the figure for water consumption should be taken at 0·5 lb. per pound of fuel as a maximum.

Nearly a year later this vehicle, then in a worn-out condition, was put through another series of trials and then only consumed an average of 3·2 lb. per vehicle-mile. Owing to the bad condition of the fire grate, due to various fuel experiments, a large portion of the fuel passed through unburned. This and the generally bad quality of the fuel provided accounted for most of the extra consumption. The results obtained on petrol vehicles are sufficiently good to encourage the production of a vehicle designed for the use of this fuel, which removes one of the greatest handicaps to the development of road transport—dear fuel.

The Field of Application.—The field of application of producer gas to vehicle propulsion is very wide. The first and largest application will undoubtedly be to the heavier type of commercial vehicle. With light commercial vehicles and cars there may be some opening, but the author has never considered this seriously, as one of the chief advantages with these vehicles is rapid starting, and consequent usefulness for short journeys. A producer-gas vehicle, using coal, cannot start from all cold in less than 14 minutes to 15 minutes, and although it is possible to keep the fire alight for a week and get away at any time in 5 minutes, even this delay is serious, and was one of the chief reasons for the death of the steam-pressure car.

An attempt is now being made to fit a producer to a light car. The author is not very favourably impressed with this application, which will reduce the producer to practically model dimensions, but it is quite possible that there may be a demand for this fuel for cars, owing to the great saving in running cost possible by its use, and the fact that it would enable vehicles to be run in places where liquid fuel is difficult to obtain.

By running the heavy vehicles, which have a very short mileage per gallon of petrol, on producer gas, it would release more petrol for light vehicles, and might have some effect on the price.

For agricultural tractors, producer gas should have a wide scope. The cost of liquid fuel is a very serious consideration in agricultural work, and has undoubtedly restricted the use of internal-combustion tractors and ploughs up to the present. In many districts, local fuel could be used in the producers, giving power at practically no cost, and this should be reflected in the price of food and living generally.

For road rollers, heavy road tractors and other uses where a considerable amount of power is required, and it has been too costly to use petrol, internal-combustion engines can now be used. For most purposes where internal-combustion engines, using liquid fuel, are in use on any form of vehicle, producer gas could be substituted without difficulty and with a great saving in fuel cost.

Effects of Producer Gas used in a Petrol Engine.—As a considerable amount of use may be made of producer gas in engines designed for petrol, some notes on the effect of this fuel on such engines may be of interest. In the first place, it was found that by using producer gas, lubrication troubles and troubles with carbon deposit caused by the present heavy petrol were greatly relieved. Producer gas has no diluent effect on lubricating oil, and thinning out of the oil, with its consequent troubles, does not occur. The pistons also remain practically free from deposit, and it would only be necessary to decarbonise these at very long intervals, if at all.

With some engines with enclosed valves, trouble is likely to arise from the lubricating oil charring or carbonising on the valve stems when producer gas is used. With petrol, this does not often happen, as the petrol vapour thins out the oil and prevents it caking. Even some petrol engines, however, are subject to this trouble, and this would be aggravated if producer gas were used.

Generally speaking, brass or gun-metal should not be used in contact with the gas, though the author has not found any ill effects on the induction pipes, &c. Knocking or "pinking" never occurs with producer gas, even if the speed of the engine is greatly reduced by the load, and with the ignition fully advanced, and it is very surprising how the engine will continue to pull up an incline without changing gear, until it is just turning over. It is not advisable to do this, as the power of the engine is proportionate to its speed, but it is an interesting point as showing the flexibility of the producer. The use of unwashed gas has not been found to cause any deleterious effects on the metal of cylinders, valves or pistons, which remain clean.

Some difficulty in starting up after a long run was experienced when using sparking plugs of the type having a stout central electrode and a thin wire electrode bent over from the shell. Examination showed that the heat had caused the thin wire electrode to drop away from the central electrode, and if this was bent back again, the plug would function satisfactorily until the engine was again stopped and allowed to get cold. This would seem to indicate that although the total heat evolved per charge with producer gas is less than that of petrol, the flame temperature is higher, as this trouble did not arise with petrol. The substitution for this type of plug of the type in which the central electrode is surrounded by a corrugated edge disc, quite removed the trouble. The sparking plugs keep very clean indeed on producer gas. No serious trouble is, therefore, to be anticipated in the use of producer gas in an engine designed for petrol, apart from that of loss of power which is dealt with elsewhere.

Upkeep.—The upkeep cost of the producer is a point which is frequently raised by those who are considering its application to motor vehicles. The working parts or parts liable to need renewal are the fire-bars and the refractory lining. The mechanically-operated parts of the producer, owing to the very low speed, will seldom require attention during the life of the vehicle, but the lining and firebars require periodical renewal. The cost of fitting a new lining is made up chiefly of the labour involved in the taking down and re-erection of the producer. A lining should run approximately 10,000 miles, which can be taken as a year's work for the majority of lorries, and a set of firebars should have the same life. The cost of fitting the new lining would be about 2*l.*, including the lining, while the cost of the new bars per set would be approximately 15*s.*, though a whole set is seldom required, the centre bars going first. As the bars can be fitted without dismantling the producer, little labour cost is involved. The upkeep cost is, therefore, very low and presents no obstacle to the adoption of producer gas.

Exhaust Gas Analysis.—Assuming the possibility of large numbers of vehicles running on producer gas being used in congested traffic areas, it was thought advisable to examine the exhaust gases emitted by such a vehicle while running in dense traffic. For this purpose, an opening was made in the exhaust manifold, and from this, samples of the exhaust gases were taken while the vehicle was running at different speeds and on different gears. The route chosen was a typical London omnibus route and included congested areas at the busiest hours. The analyses are given in Table IV, and it will be seen that no apprehension need be felt that any annoyance will arise from the use of producer gas on vehicles in towns, the results comparing very favourably with those from the exhaust of petrol-driven vehicles.

TABLE IV.

Description of Test.		Analysis. Carbon Di-oxide. CO_2.	Free Oxygen. O.	Carbon Mon-oxide. CO.
Engine idling.	400 r.p.m...	14·1	3·4	nil
4 m.p.h.	800 r.p.m...	14·0	1·6	nil
6 m.p.h.	700 r.p.m...	7·0	1·8	nil
8 m.p.h.	700 r.p.m...	5·0	0·6	nil
9 m.p.h.	800 r.p.m...	5·1	3·1	nil
8 m.p.h.	600 r.p.m...	14·5	1·3	nil
6 m.p.h.	500 r.p.m...	6·2	nil	1·9
5 m.p.h.	800 r.p.m...	9·4	nil	2·0
5 m.p.h.	600 r.p.m...	7·0	3·9	nil
Engine idling	.. .	11·1	4·4	nil

It should be noted that these tests were taken from an engine with a compression pressure of only 65 lb. by gauge, and thus not suitable for the economical use of producer gas. The range of ignition advance was also insufficient.

Waste Gas Analysis.—When a vehicle fitted with a producer is standing with the engine stopped, it is advisable to open the gas test cock or the fuel feeder opening to allow ventilation to the fire and so tend to keep it in a condition suitable for rapid starting. It was therefore considered necessary to ascertain the composition and volume of the gases which would be emitted under those conditions, and these are shown in Table V. In considering this it should be remembered that there is no flow of steam through the fire while the plant is standing. The most important point is the volume, which was gauged at 10 cub. ft. per hour, and this, when the vehicle is standing in the open, can be regarded as negligible. When standing in a garage, it is certainly less dangerous than the engine exhaust of a vehicle, but it is nevertheless advisable to provide good ventilation in any garage where such vehicles are housed.

TABLE V.

—	Gas off 3-Way Vent Cock, after returning Home. Engine Stopped.			
	1*st Sample.*		2*nd Sample.*	
	per cent.		per cent.	
Carbon dioxide ..	2·20		5·20	
Free oxygen	1·20	After	3·70	After
Carbon monoxide ..	7·00	5	11·70	10
Heavy hydrocarbons	nil	minutes'	nil	minutes
Nitrogen	80·00	stoppage.	53·90	stoppage.
Combustible matter ..	9·60		25·50	

Danger from Fire.—The danger from fire due to the use of producer gas is very remote, though it would certainly be inadvisable to light or to rake out the fire in an ill-ventilated garage containing petrol vehicles. Fire could only occur from some outside cause such as a leakage of petrol in the garage in which the producer gas vehicle was standing. While the engine is running, there is no chance of fire, but with the producer open, petrol vapour, if present, might be ignited. It would, therefore, be advisable not to house petrol and producer-gas vehicles in the same shed at night, unless very well ventilated. In this respect, however, the producer-gas vehicle would be a much safer companion for a petrol vehicle than a steam lorry.

In this connection, the Interdepartmental Committee on the employment of gas as a source of power, in their recommendation No. 37, make the following statement:—

"A vehicle deriving its power from a portable, self-contained, suction gas producer should not be housed under living rooms in human occupation, or while the fire is alight be stored overnight in the same building or enclosed structure as a petrol-driven vehicle."

Fuels.—In dealing with fuels, the author proposes to limit his remarks to such points as apply to those fuels when used on vehicles to furnish producer gas. The chief fuel is anthracite, and if this can be readily and cheaply obtained it is advisable to use it. Anthracite can be got in many sizes or grades. That which is required for the small producers used on vehicles is termed "beans" and passes through a ¾-in. or ½-in. mesh. It should invariably be sieved before use in order to eliminate any dust. If bought in truck lots from a colliery, it will be received washed and screened ready for use. Anthracite is not generally stocked by local coal merchants, and the author has several times had a mixture of bituminous coal of all sizes, from dust to that of a brick, delivered in lieu. A cubic foot of anthracite weighs from 90 lb. to 102 lb. according to the specific gravity. A cubic foot, if broken up to the size of "beans," weighs approximately 58 lb. A cubic foot of petrol weighs approximately 48 lb. In a given space, therefore, 20 per cent. more weight of anthracite than of petrol can be carried.

If the consumption of anthracite is taken as 20 per cent. more by weight than petrol, the space occupied by fuel for any given distance would be equal, but the weight of coal would be greater.

Good anthracite should have a calorific value of 15,000 British thermal units to 15,500 British thermal units per pound, and should consist of carbon 90 per cent. to 93 per cent.; hydrogen 4 per cent. to 4·5 per cent.; oxygen 3 per cent. to 5·5 per cent., as against petrol, 85·2 per cent. carbon and 14·7 per cent. hydrogen, and a value of 18,500 British thermal units per pound. The best depth of fire bed in the author's producer, for anthracite, is 6 in. Anthracite is clean to handle, safe to store gives off no dangerous vapours, and being very smooth in surface, works well down chutes or fuel pipes from the hopper to the producer.

Coke.—Gas coke, while quite suitable for vehicle work is more bulky than anthracite. It has already been subjected to one distillation, and, therefore, any volatile constituents left in it are hard to deal with. The composition of the fuel also depends on the class of coal from which it is produced and the treatment to which it has been subjected. It is by no means such a clean fuel in use as anthracite. The sulphur content is over twice that of anthracite, and for vehicle work, where a dry scrubber alone is possible, this is a drawback. The ash percentage also is over double that of anthracite, 5·8 as compared to 2·2, and the calorific value is 13,500 British thermal units. The ordinary analysis gives carbon 88 per cent.; hydrogen 0·02 per cent.; oxygen up to 3 per cent. The weight of a cubic foot of broken coke is approximately 34 lb. The space occupied is therefore, large in proportion to anthracite, especially in view of its lower calorific value. It is, however, a fuel

which is readily obtainable and is usually cheaper than anthracite; it can be bought broken and screened to the size required; it is clean to handle and safe to store, but owing to its rough surface, it does not feed so well as anthracite.

In working with coke, a larger quantity of water is required per pound of fuel than with anthracite, and this is readily obtained in the author's system by altering the stroke of the water pump and the setting of the steam throttle. It is possible to use coke without this alteration, but as it only takes 2 minutes to 3 minutes and gives much better results, it is worth doing. The best depth of fuel bed is 7 in.

Charcoal.—Charcoal is a very suitable fuel for vehicle work. Apart from its light weight per cubic foot, which is approximately 17 lb. to 18 lb., and the large space occupied compared to petrol to cover a similar distance, it has practically no drawbacks. The calorific value is approximately 14,000 British thermal units. It should be broken to the same size as anthracite. It is possible to get away very quickly by using charcoal, a start from cold having been made in 10 minutes. The ash is very light and liable to be drawn over into the scrubber so that if this fuel is to be used exclusively, either a larger filter box must be fitted, or the scrubber must be cleaned out at shorter intervals. It has a very wide distribution and is often available in districts where coal and oil are unobtainable. With this fuel, a thinner fire bed is required, the best results having been obtained when the depth was maintained at 4 in. With light fuels, such as charcoal, the range of the vehicle would be reduced considerably as compared with petrol, owing to the large bulk occupied by the fuel, but no difficulty should be experienced in having fuel stations along the roads, and these would only have to be utilised for long journeys. A 3-ton vehicle should run on 3 lb. of charcoal per mile so that 1 cub. ft. would run 6 miles. Six cub. ft. or 8 cub. ft. could be readily carried on such a vehicle, so that a range of 40 miles to 50 miles could be covered on one fill-up.

Peat.—Peat did not at first appear to be a very suitable fuel for vehicle work, and the first trials, which were made with ordinary dried peat, which contained 64 per cent. of volatile constituents, were not satisfactory. This percentage was quite beyond the capabilities of the plant and effectually tarred up the engine after only a short run. When, however, compressed and dried peat was used, the results given were extremely good and exceeded those given by either charcoal or coke. The peat is compressed into briquettes and afterwards dried to drive off the moisture and troublesome volatile matter. The result is a fuel which is eminently suitable for producer work, especially on motor vehicles, as it enables a rapid start to be made and gives an extremely clean gas of high calorific value and needing little scrubbing.

When broken into suitable pieces, the weight per cubic foot is approximately 47 lb. The dried peat breaks readily into suitable sizes and is not friable, so loss from dust is negligible. One peculiarity with this fuel is the shallow fuel bed required, a depth of 2 in. to 3 in. giving the best result, though satisfactory running has been obtained with a bed only 1½ in. thick.

The producer for this fuel could, therefore, be of very small dimensions, but the ordinary size of anthracite producer has so far been used. Peat has a wide distribution, and its satisfactory adoption must be of enormous assistance in spreading the use of the internal-combustion motor vehicle, especially for agricultural work. The author was informed that the fuel could be supplied at approximately 16s. per ton. If this is so, it would be equivalent to petrol at little over 1d. per gallon.

The peat fire will remain alight many hours ready for an almost immediate start, while starting from all cold can be accomplished in from 7 minutes to 10 minutes. The author is convinced that satisfactory use of this fuel is only possible by his system of a thin, constantly-agitated fire, constant feed, and control of the air and steam supply.

Maize Cobs.—Maize cobs are the centres or stems of the maize after the grains have been removed. Through the kindness of a friend in the Argentine, the author received a small supply of this material, and tests show it to be a very suitable fuel. Owing to its shape, it is easily broken into suitable sizes and is then very easy to feed.

Unfortunately, the quantity of material available did not allow of any figures being obtained, but it was sufficient to demonstrate that this material would be a very valuable fuel, especially in districts in which it is grown, where it is largely a waste material. Some use is made of it, the author understands, for steam raising, but it could be used to much better advantage in a gas producer.

Straw.—It has been calculated that the straw destroyed or worked back into the ground annually in Western Canada alone would, if used in producer gas plants, give an equivalent of 470,000,000 gallons of petrol.

Other fuels will, no doubt, be found, which are quite suitable for vehicle propulsion, but enough has been said to show how much the fuel field has been widened by the use of a gas producer adapted to motor vehicle work. All the above fuels cannot be cornered or juggled with financially, and as they can all be used without any trouble or drawback in producer gas plants the motor industry need not be entirely in the hands of the liquid fuel ring any longer.

In conclusion, the author desires to thank the Army Council and the Ministry of Munitions Inventions Department for the facilities granted for completing his experiments. He has dealt with the application of his plant to motor vehicle work, but it will readily be understood that this only represents a very small portion of the possible field of application.

FAILURES OF TURBO-GENERATORS AND SUGGESTIONS FOR IMPROVEMENTS.*

By J. SHEPHERD.

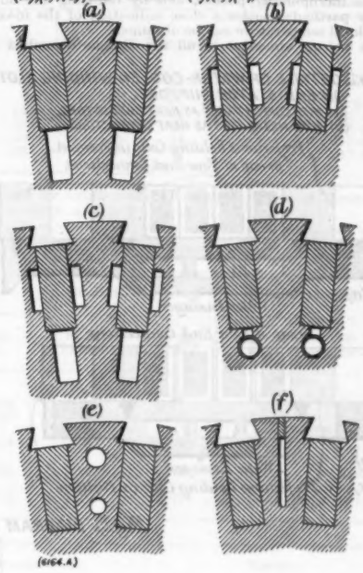
(*Concluded from page 46.*)

IDEAL MACHINE.

Consideration of the usual defects already mentioned shows that air ventilation gives rise to the following difficulties:—

Fig. 8. STATOR WINDING, VARIOUS METHODS OF COOLING.

(a), (b), (c), Air Cooled. (d), (e), (f) Water Cooled.



1. Impossibility of equal distribution of air with presence of hot spots;
2. Weak construction of stator, open type of end windings and serious fire risks;
3. Larger diameter of rotor with greater centrifugal forces; inadequate cooling of end winding loops;
4. Higher temperatures than desirable, with reduced life of insulation.

The ideal machine must be free from these defects, and should also embrace the following features:—

(a) Coils to be continuously held against movement under mechanical forces, but free to expand with heat.

(b) Working temperature and output independent of air conditions.

(c) Capable of working at a much reduced temperature and to be practically fireproof.

Machines constructed to embrace these features would undoubtedly be much superior to those at present manufactured, if the modifications do not introduce other difficulties either in construction or in operation.

To obtain these advantages, all windings, including rotor end loops and stator end connections, would be contained in continuous metal winding slots, with adequate freedom for expansion. The windings would be securely supported over their entire length, and the heat generated in the copper would be directly conveyed to the surrounding supporting metal, and dissipated by liquid cooling.

Arrangement.	Proposed by.	Size of Ducts taken on Illustration.	Relative Cooling Capacity.
Fig. 8 (a)	Ordinary arrangement	2½ in. by 1 in., one air duct	1
Fig. 8 (b)	Siemens ..	2 in. by ½ in., two air ducts	0·8
Fig. 8 (c)	Schuckert ..	2½ in. by 1 in., one air duct; 2 in. by ½ in., two air ducts	1·8
Fig. 8 (d)	Parsons ..	1-in. water tube ..	54
Fig. 8 (e)	Siemens Dynamo Works	1-in. and ½-in. water holes	83
Fig. 8 (f)	Author ..	3½-in. by ½-in. water slot	89

Various designs have been proposed using liquid cooling. Whilst the majority of them are of foreign origin the initial adaption of water cooling to modern machines is to be credited to Messrs. C. A. Parsons and Co., Limited.

All the liquid cooling designs on record appear to deal with the problem of heat dissipation as an adjunct to air cooling. If, for the moment, the principle of liquid cooling be accepted and be completely developed as a practical feature, there are a number of important modifications which at once become possible. Air ventilation, with the difficulties of cooling and cleaning, becomes unnecessary, and the fire risk of machines largely disappears if there be no air to feed the flames. By splitting up the water paths in the machine, and by providing adjusting cocks in the water supply to each cooling device, it becomes a simple matter to determine the temperature of each part of the machine and to adjust the water flow to give a uniform temperature with elimination of hot spots, and having regard to the superior cooling effect of water over air, a lower temperature would be possible with enhanced life of the insulation.

A further and great advantage would be in the provision of continuous supports to the end connection of both stator and rotor windings, which at present are the weakest features of most generators.

As a more detailed comparison of the two methods of cooling, various designs of cooling rotor windings have been drawn out for a modern high-speed rotor (Fig. 8).

Taking the ordinary air velocities in rotor ducts as 10,000 ft. per minute, and a moderate water velocity

Fig. 9. ROTOR WITH SEPARATE COIL SUPPORTS, WATER-COOLED.

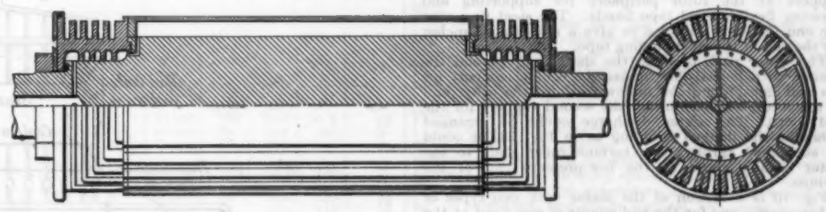


Fig. 10. STATOR WITH WATER-COOLED COIL SUPPORTS.

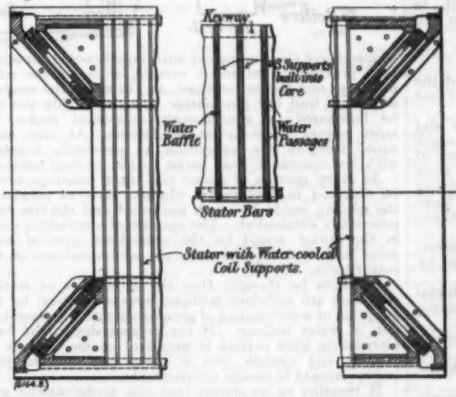
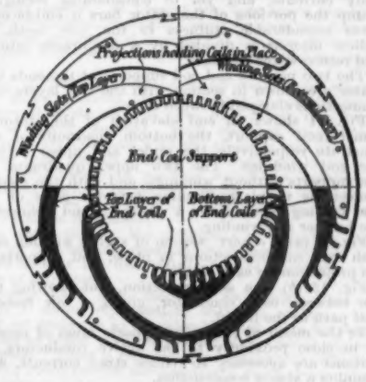


Fig. 11. DETAILS OF WATER-COOLED END-COIL SUPPORTS.


Projections holding Coils in Place
Winding Slots (Top Layer)
Winding Slots (Bottom Layer)
End Coil Support
Top Layer of End Coils
Bottom Layer of End Coils

* Paper read before the Institution of Electrical Engineers, January 8, 1920.

of 500 ft. per minute (8·3 ft. per second), the relative cooling capacities of the streams of air and water are as shown in the table on page 95.

The sizes of cooling ducts are taken as large as can be constructed with the winding slots shown, viz.

Slots, 5 in. deep by 1¼ in. wide; coil space, 4 in. deep by 1¼ in. wide; tooth width at periphery, 3 in.; 40 in. diameter rotor.

The actual heat-abstracting powers of the two sets of conditions per degree F. rise in temperature of cooling medium for the velocities stated are :—

Air : 1·266 therms per minute per square inch of air duct.
Water : 216 therms per minute per square inch of water duct.

The capacity of water over air cooling is very marked, as might be expected, and may be in excess of the capacity of the insulation to conduct the heat, a matter considered later. A rotor constructed with cooling ducts as shown in Fig. 8 (*f*) is detailed in Fig. 9, where water-cooled supports are shown for the end loops against sideslip.

Water cooling for the stator does not appear to have been developed to any great extent; hollow water-cooled stator frames have been designed by Herr E. Huther, and I am informed that a few machines were constructed by the A.E.G. on these or similar lines, but not of recent years.

Geisenhorner, of Schenectady, proposed cooling devices of thin stamped metal for building into the stator core, but I have found no record of machines using these devices having been constructed.

Combination of Water Cooling and Coil Supports.

If full advantage is to be taken of water cooling, it would appear desirable for the cooling arrangements to be in close proximity to the coils, with very low resistance heat paths, and to serve the double purpose of coolers and coil supports. Designs have been developed by the author upon these lines, and are indicated in diagram form in Figs. 8 (*f*), 9, 10, 11, 12 (*a*) and (*b*), and 13.

A short description of each may be of interest.

In Fig. 8 (*f*) the heat from the rotor coils is directly transmitted to the iron tooth, which would be made slightly wider than usual to compensate for the loss in section where the water duct is milled out of the solid tooth; the top of the duct is closed by a steel plug, fusion-welded in place.

Fig. 9 shows a rotor with teeth cooled as described, and provided with separate bronze coil supports at each end of the core. The supports would provide continuous slots for the end loops of the rotor coils. The metal teeth between the coils give substantial support at the rotor periphery for supporting and entering flexible steel tape bands. The steel ring over the end flange is arranged to give a mechanical anchor for the end of the steel binding tape.

The water path is along the shaft from beyond the exciter with helical flow under the cooling support for the end loops, along the hollow teeth to the other end of the rotor, helically under the second support for the end loops. The water discharge could be arranged either at the flanged coupling as in Fig. 13, or could be continued through the turbine rotor shaft to the water sealing gland at the low-pressure end of the turbine.

Fig. 10 is a section of the stator with two types of coil supports, one for the end windings and fixed at the ends of the core, and the other built into the core between batches of laminations. This latter support is constructed with the inner part laminated to reduce eddy currents, and yet of considerable strength to clamp the portions of the stator bars it embraces and gives considerable stiffness to the core teeth. The hollow interior is divided by a diaphragm into flow and return water passages.

The two pairs of end coil supports at the ends of the stator are shown in section with the two layers of end connections clamped between them.

Fig. 11 shows an end elevation of the stator end (inner) coil support, the bottom quadrants of which illustrate respectively the under and upper layers of the end windings. The two upper quadrants show the supports without windings, and with the clamping projections in place, forming between pairs of them the winding recesses for a group of end connections, one bar per slot winding.

Fig. 12 (*a*) is a part section of such a winding recess, with four end connections in place, and supported by the projection on each side.

Fig. 12 (*b*) is a similar section, but showing metal fins between each conductor, giving a low resistance heat path to the liquid.

As the metal of the coils supports must of necessity be in close proximity to the active conductors, precautions are necessary to reduce stray currents, whilst retaining a strong construction.

Figs. 12 (*a*) and 12 (*b*) show the coils clamped directly over a water cooling duct cast in the support and enclosed by a metal plate fusion welded in place. The plate must have considerable mechanical strength and high electrical resistance.

Copper-nickel alloys are on the market, which are as strong as high-quality bronze, and have over 20 times the electrical resistance of copper. Their use would reduce the stray currents to a comparatively insignificant loss.

Water Cooling.

When arranging the water circulating system, due regard must be paid to the risk of corrosion and to the recommendations of the Corrosion Committee of the Institute of Metals, viz. :—

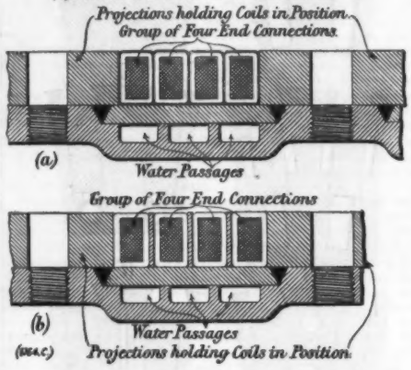
1. Only clear water to be used.
2. Water to be free from gases in suspension or solution.
3. Water must be neutral, or only very slightly alkaline.

To comply conveniently with these recommendations, the cooling water is taken from the condensate of the steam turbine, forced by the extraction pump through the cooling devices of the alternator and discharged into the turbine hotwell. The whole of the heat losses in the alternator would then be utilised. With modern high vacua the temperature of the condensate is from 70 deg. to 80 deg. F., which temperature would then receive an increment of from 13 deg. to 15 deg. F.

The return flow of each water path is shown provided with a thermometer pocket, and by reducing the flow in any particular cooler a close indication of the maximum local temperature can be obtained.

The objects aimed at in all the designs described is to interleave the conductors with liquid-cooled supports, thus providing continuous winding slots for the coils, coil loops and end connections, &c., in which the weakest and most frail bar (no matter how thoroughly the bar be laminated) is continuously supported under the most severe short-circuit conditions. At the same time, freedom for expansion is provided, together with low-resistance heat paths to the cooling medium.

Fig. 12. DETAILS OF WATER-COOLED WINDING SLOT ON END STATOR SUPPORT.
(a) WITH COPPER TAPES AS HEAT CONDUCTORS.
(b) WITH METAL FINS AS HEAT CONDUCTORS.



As every portion of stator and rotor windings would be enclosed in cool metal winding slots of necessity, the cooling would be much improved and the fire risks practically eliminated. The absence of ventilating ducts in the stator would be the immediate gain of solid cores and firm support over the entire surface of the stator teeth.

It might be thought that the difficulties of station engineers are sufficient without increasing them by the adoption of water cooling of generators with the attendant risk of water leakage. If the present designs of large alternators were perfect it would of course be folly to suggest any change, but it must be admitted that improvements in design are desirable.

It remains to be shown that the modifications proposed, while removing certain difficulties, do not give rise to others which are greater.

The problem in the plainest terms is the possibility of constructing stator cooling devices capable of withstanding a water temperature of about 120 deg. F. and a pressure of 50 lb. or less per square inch, whilst at the same time the devices must have sufficient strength to withstand the short-circuit stresses on the stator. The rotor-cooling devices are subjected only to the internal water pressure and stresses resulting from centrifugal forces. Adequate mechanical strength can be given to these devices by the use of suitable material, proportioned in accordance with well-known methods now used in all branches of engineering industry.

With respect to the prevention of water leakage, all joints can be constructed of a character similar to those used in hyrdaulic practice, and dealing with the pressures of over 2 tons per square inch, or in accordance with steam practice, with high-pressure superheated steam of 300 lb. pressure per square inch and a temperature of 700 deg. F. Fusion welding is now an accepted construction for the more arduous requirements of high-pressure boilers and steam piping. Moreover, the fusion-welded water joints may be designed so that the weld is subjected to no other stresses than those caused by the internal water pressure. Consequently, combining skilful design, stout construction and reliable workmanship, one can ensure no movement of the coils, no leakage of the water devices, and no overheating of the coils. Under such conditions, failure of machines should be infrequent. Should, however, a short circuit in a machine occur, the walls of the cooling ducts may become fused, in which extreme case a jet of water would immediately flood the machine; but even so, this flooding by water would only occur after a burn-out had happened, and in such circumstances a stream of water playing upon the fire would certainly be better than a fierce blast of air. In all cases, prevention is better than the best remedy, and the improvements suggested are all of preventive character.

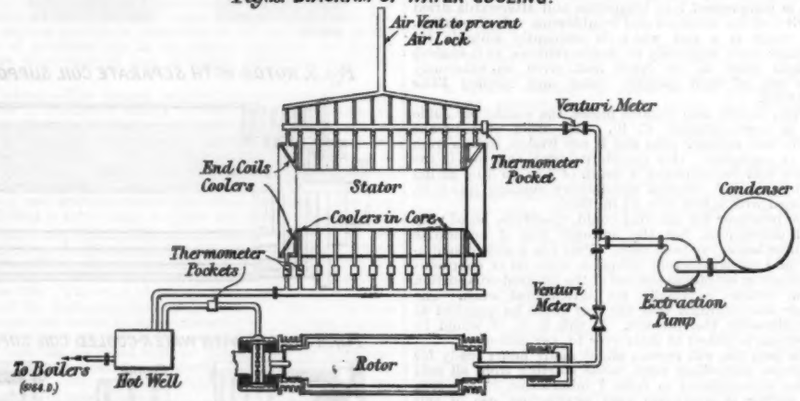
It will be seen, therefore, that whilst water cooling will remove many, if not all, of the risks inherent in the ordinary air-cooled machine, there is nothing in its application that prevents any real difficulty or introduces any method of construction which has not been established in other branches of engineering.

General Comparison of Air and Water Cooling.

In modern turbo-generators of large capacity, over 95 per cent. of the heat is carried off by the ventilating air. Assuming for simplicity that all the losses are dissipated by either air or water circulated through the machines, the relative quantities of each can be calculated from the following data :—

J = mechanical equivalent of heat, taken as 778 ft.-lb.
1 kw. = 3,412 therms per hour.
= 56·82 therms per minute.
Specific heat of air = 0·237.
Specific heat of water = 1·0.
Weight of 1 cub. ft. of air = 1/13 lb. at 60 deg. F. and 30 in. barometer.

Fig. 13. DIAGRAM OF WATER COOLING.



Weight of 1 cub. ft. of water = 62·35 lb. at 60 deg. F.

Comparative cooling effect of

$$\frac{\text{1 cub. ft. of water}}{\text{1 cub. ft. of air}} = \frac{62 \cdot 35}{0 \cdot 237 \div 13} = 3{,}420.$$

Max. velocity of air in external air ducts, say, 1,500 ft. per minute.

Max. velocity of water in external water pipes, say, 200 ft. per minute.

Allowing a temperature rise of 50 deg. F. for both air and water :—

Amount of air required per minute for 1 kw. loss

$$= \frac{56 \cdot 82 \times 13}{0 \cdot 237 \times 50} = 62 \cdot 34 \text{ cub. ft.}$$

To allow for air short-circuited or not properly distributed, say, 100 cub. ft. per minute.

Area of external air duct per 1 kw. loss

$$= \frac{100}{1{,}500} = 0 \cdot 066 \text{ sq. ft.} = 0 \cdot 95 \text{ sq. in.}$$

Amount of water required per minute for 1 kw. loss

$$= \frac{56 \cdot 82 \text{ lb.}}{50} = 1 \cdot 135 \text{ lb.}$$

To allow for unequal distribution of water, say, 1·5 lb. or 0·15 gallon per minute.

Area of external water supply pipe per 1 kw. loss

$$= \frac{0 \cdot 15 \times 0 \cdot 16 \times 144}{200} = 0 \cdot 00173 \text{ sq. in.}$$

$$\frac{\text{Area of external air duct}}{\text{Area of external water duct}} = \frac{0 \cdot 95}{0 \cdot 00173} = 550.$$

The losses in turbo-generators differ with various

designs, but representative figures are given below, together with the relative amounts of air and water necessary for cooling on the liberal scale just worked out.

On the assumption that the condensate be used for cooling the proportion necessary to limit the rise to 50 deg. F. is given, also the increment of hotwell temperature.

Size of Alternator, k.w.	Internal Loss, Per Cent.	Quantity of Cooling Media. Air. Cub. ft. per Min.	Water. Cub. ft. per Min.	Water. Galls. per Min.	Size of External Ducts. Air. Sq. ft.	Air. Diameter. ft. in.	Water. Diameter. in.	Per cent. of Condensate for 50 deg. Rise.	Increase of Hotwell Temperature deg.
5,000 ..	5·5	27,500	6·6	41·2	18	5 0	2½	41	15·5
10,000 ..	5·0	50,000	12·0	75·0	33	6 6	3½	39	15·0
20,000 ..	4·5	90,000	21·6	135·0	59	8 9	4½	36	13·5
50,000 ..	4·0	200,000	48·2	300·0	133	13 0	6½	32	12·5

TABLE GIVING HEAT DENSITY IN WATTS PER SQUARE INCH OF CONDUCTING AREA FOR VARIOUS TEMPERATURE GRADIENTS, AND FOR HEAT PATHS 0·10 IN. AND 0·20 IN. LONG.

Class of Heat Conductor including Ordinary Insulation Copper and Air Cells.	Heat Density in Watts per Square Inch. Gradient, 1° F. 0·10-In. Path.	Gradient, 1° F. 0·20-In. Path.	Gradient, 50° F. 0·10-In. Path.	Gradient, 50° F. 0·20-In. Path.	Gradient, 100° F. 0·10-In. Path.	Gradient, 100° F. 0·20-In. Path.
Copper	45·0	22·5	2250	1125	4500	2250
Mica plates without air spaces	0·0508	0·0254	2·54	1·27	5·08	2·54
Empire cloth and mica in alternate layers tightly wrapped	0·0295	0·0147	1·47	0·735	2·95	1·47
Empire cloth and mica in alternate layers with usual air spaces	0·0206	0·0103	1·030	0·515	2·06	1·03
Micanite, with 11 per cent. shellac as binding material	0·0172	0·0086	0·86	0·43	1·72	0·86
Still air (air cells)	0·0028	0·0014	0·14	0·07	0·28	0·14

Class of Ship.	Displacement.	Length.	Speed.	Shaft, h.p.	Generators. Cooling Air. Cub. Ft. per Min.	Air Duct Area.	Diam.	Cooling Water. Galls. per Min.	Diam., Pipe.	Motors. Cooling Air. Cub. Ft. per Min.	Air Duct Area.	Diam.	Cooling Water. Galls. per Min.	Diam., Pipe.
	tons.	ft.	knots.	approx.		sq. ft.	ft.		in.		sq. ft.	ft.		in.
Tramp	13,500	420	10	2,500	12,000	6	2·8	18	1½	11,000	5½	2·8	16·5	1½
Intermediate ..	17,500	500	14	10,000	45,000	22½	5·4	67·5	3½	40,000	20	5·0	60	3
First-class passenger	20,000	550	19	21,000	85,000	42½	7·4	128	4½	78,000	39	7·0	117	4½
First-class Atlantic liner	33,000	760	25	68,000	250,000	125	12·8	375	7½	225,000	112½	12·0	338	7
Small cruiser ..	3,500	400	30	40,000	165,000	82½	10·3	250	6	150,000	75	9·9	225	5½
Super "Dreadnought"	25,000	600	25	27,500	115,000	57½	8·7	170	5	100,000	50	8·0	155	4½
Battle cruiser ..	33,000	860	35	180,000	600,000	300	19·6	900	11½	550,000	275	18·9	825	11

Velocity in external air ducts taken at 2,000 ft. per min. Velocity in external water pipes taken at 200 ft. per min.

The relative cooling capacities of the internal stator ducts of equal volume would be :—

Water ducts with water velocities of 500 ft. per min. / Air ducts with air velocity of 4000 ft. per min. = 420.

This increased potential capacity for cooling might be in excess of the capabilities of the remainder of the machine to transmit the heat to the cooling ducts through the insulation around the copper.

The laws of thermal capacity are very similar to Ohm's law and may be stated thus :—

A (heat) current passing through a (thermal) resistance gives rise to a difference of pressure (temperature) across the resistance. In other words a hot insulated conductor passing heat through the insulation is always hotter inside the insulation than on the outer surface of the insulation being cooled. As the interior surface of the insulation must never exceed the safe temperature of the insulation, no matter how cold be the outside of the insulation, a limit to the maximum heat flow through the insulation is soon reached.

The thickness of insulation usually lies between 0·1 in. and 0·2 in., and the transference of heat measured in watts per square inch for various kinds of insulation is given above for heat gradients of 50 deg. and 100 deg. F. For comparison the corresponding figures are also given for still air (without convection) and for copper.*

For example, a stator coil with insulation 0·10 in. thick has an outside temperature of 100 deg. F., and is insulated with micanite built up with 11 per cent. shellac. If the inside temperature is not to exceed 150 deg. F. the temperature gradient must be 50 deg. F. or less; to be within that figure, the heat density must not exceed 0·86 watt per square inch of that portion of the insulation which is conducting away the heat.

In the case of the rotor coil shown in Fig. 8 (*f*) all four faces of the coil may be considered to be effective heat conductors.

With water-cooled stator end connections having several conductors in the same winding recess (Fig. 12*a*) only one face is usually in contact with the cooling device, and the other three faces of insulation are not freely conducting. The thermal conductivity can be improved by wrapping copper foil around the coil giving a direct heat path from all four faces. The conductivity of copper to micanite (11 per cent. shellac) is 2,600 : 1.

In the case of iron losses, each cooling element is in direct contact with groups of stampings, and the heat path is both small in length and considerable in area.

The cooling effect of water is so considerable that without certain precautions, condensation difficulties may arise. If the temperature of the cooling devices falls below the dew-point atmospheric condensation upon them will take place. This can be avoided by using cooling water with an inlet temperature higher than the dew-point, as by the method shown in Fig. 13.

As the output of most machines is rated by ultimate temperature, there are substantial grounds for concluding that water cooling will allow an increase in output for the same total weight and volume of 25 per cent. to 33 per cent. Some readjustment of relative copper and iron losses may be necessary, and the result should be a substantial reduction of average temperatures and weight for the same output. Whether water cooling will displace air cooling, time alone can prove.

There are, however, a number of cases where water cooling offers advantages over air cooling, quite apart from the improved and more robust construction of machines, *i.e.*, for machines working under the following conditions :—

1. In hot climates where cool air is difficult to obtain.
2. In extremely dirty and sulphurous atmospheric conditions.
3. At high altitudes with reduced air density.
4. On board ship, where air cannot be freed from salt spray.

As an example of turbo-generators working at high altitudes, the stations on the Rand may be cited. At an elevation of 6,000 ft. and a barometer of 24·5 in.* the air density would be 82 per cent. of normal, and a standard turbo-generator frame of 10,000 k.v.a. would only be suitable for an output of approximately 8,500 k.v.a. air-cooled. The same frame if adapted for water cooling would probably give an output of 12,500 k.v.a.

Consequent upon the higher ambient temperature of the South African climate, water cooling would have the further advantage of a much lower average temperature of windings.

The last case deserves detailed consideration.

SHIP PROPULSION.

The field for the electrical propulsion of ships is practically virgin and immense in size.

In order to gauge the size of the power problem involved, the particulars of various representative classes of ships are given, taken from published figures. From them the relative quantities of cooling air and cooling water are calculated. The generators are assumed to have the losses already given for land service. The motors may be either high-speed machines geared down to the propeller shafts, or low-speed direct-coupled. In either case the same internal losses have been assumed, and these will be sufficiently accurate for the present rough examination. If the motors were low-speed, direct-coupled to the propeller shafts, they would be of open-type construction; of necessity they would be housed in small watertight compartments, and, so far as ventilation is concerned, may be considered to be enclosed machines requiring auxiliary cooling, except for the smaller powers.

The electric power would be either two-phase or three-phase, with a pressure of approximately 1,000 volts for small ships, increasing to about 14,000 volts for the larger powers, otherwise the size of the conductors and operating switch gear would be too heavy and costly.

The one great difficulty with even low-pressure electrical plant for ship work is the presence of salt water. Electrical apparatus quite suitable for land service usually requires modification to suit sea conditions and, up to the present, high-tension apparatus of any considerable power has not been used to any extent under severe sea conditions.

The difficulties peculiar to sea service are due to the extreme weather conditions encountered. In the course of a voyage a ship may meet air temperatures varying from 0 deg. to 100 deg. F., and must of necessity develop full power continuously under extreme Red Sea summer conditions, with day temperatures of 105 deg. to 115 deg. F. falling at night to 95 deg. F.

Again during heavy gales waves may sweep the ship from end to end, with spray continually blown over the tops of the funnels. Such rough conditions may continue during an entire Atlantic voyage, and the salt water finds its way into practically every part of the ship.

It is difficult to see how the cooling air can then be collected in large volumes free from salt spray. Air washing might get rid of the larger portion of the salt, but its operation in frosty weather would be difficult, and plant difficult to operate is not required at sea.

Apart from operating troubles, the question of room must be considered.

The sizes of air ducts are calculated for a high velocity of 2,000 ft. per minute. They are of considerable dimensions, and it is doubtful if any shipowner would sacrifice valuable carrying space to accommodate them. The situation of the generators and motors would be aft of midships, and short vertical air ducts to them would cut through state-rooms and saloons of liners, the most valuable portions of the ship.

In fighting ships the problem is more difficult, as the powers to be developed are higher and the space is enormously costly. At present the floor space allowed for steam propulsion, including boilers, engines, auxiliaries and working gangways is generally at the rate of 10 h.p. per square foot—a figure quite unapproached in land service.

Owing to the low free-board, all cooling air would require to be collected at some height above the deck to ensure that the air was even moderately free from spray in heavy weather. Such elevated air trunks might seriously interfere with the training and firing of the guns from the aft turrets, and there would be the further complication of piercing watertight bulkheads and cutting various protective decks. The objections, in fact, might be so serious as to outweigh any advantages of electric propulsion.

With water cooling, the difficulties of collecting and conveying the cooling medium disappear, and its use presents neither the difficulties of large ducts nor the trouble of filtration.

Proposals have been made to re-circulate the air through a closed pipe system with air coolers; the sizes of air ducts are so considerable that room for them could not be found with the present allowance of engine-room space. There is now usually considerable difficulty in finding room for the comparatively small steam pipes and valves.

Whether the machine be air cooled or not, a certain amount of salt is likely to reach the windings, and, with pressures of 1,000 volts and over, watertight windings would be a great advantage. The micanite wrap on the stator bars may be considered to be waterproof without further treatment, but a waterproof seal over the end insulated joints is desirable. A substantial seal of vulcanised rubber could be "cured" in place over the insulated joints using the cooling devices as heaters, for short periods by passing low-pressure steam through those embracing the ends of the stator bars.

This waterproof treatment of the stator joints would be of advantage if surface condensation took place. The ideal alternator for marine purposes should be capable of being cleaned down with a hose pipe.

The difficulties of sea conditions have in no way been

* H. D. Symons and M. Walker: Journal I.E.E., 1912, vol. xlviii, page 682.

* J. H. Rider, Journal I.E.E., 1915, vol. liii, page 629.

exaggerated, and most of them can be overcome by adapting designs to suit sea conditions. If electrical propulsion is to progress, the problem must be attacked in a thoroughly practical way, as electrical methods will be in opposition to established interests and in competition with thoroughly sound and well-tried steam plant evolved after years of practical sea experience.

The present design of high-speed marine turbine drive is through double-reduction helical gears of fine pitch, with end-thrusts balanced by mounting pairs of helical gears with opposite angular leads. With the most perfect machining and fitting possible, the driving faces can only have lines of contact, and with the finest chrome steel gears and lubricated faces heavy drives with only lines of contacts cannot be considered to be a final solution. Up to the present, marine turbines are not supplied with superheated steam, which is in striking contrast to land practice.

CONCLUSION.

The first portion of the paper briefly reviews the chief causes of failure of turbo-generators as now constructed, and the statements will no doubt be endorsed by most engineers who have had charge of large plant.

Designs have now passed the initial difficulties of electrical and magnetic characteristics, and the secondary difficulties of mechanical strength, durability, heating and fire risk remain.

Whether we like the idea of liquid cooling or not, the question has to be faced in the immediate future, and the full consideration of its uses gives an opportunity of considering alternator design from a new point of view. The designs described offers the following advantages over air-cooled machines.

Rotor.

1. Smaller diameter with reduced centrifugal stresses.
2. Mechanical support to end winding loops and steel tape bands.
3. Efficient heat paths, low working temperature, less fire risk, and longer life.

Stator.

4. Solidly supported core and teeth with reduction of vibration.
5. Continuous mechanical support to windings.
6. Efficient heat paths, low working temperature, less fire risk and longer life.
7. Adjustment of amount of cooling to every portion, with elimination of hot spots.

The physical life of any plant, apart from breakdowns, is determined by the wear of moving parts, fatigue of such other parts as may be subjected to fluctuating stresses or, in the case of insulation, by prolonged heating combined with mechanical stresses.

Having regard to the necessarily few moving and wearing parts of a turbo-generator, viz., journals, bearings, and slip-rings, there appears to be no sound reason why it should not have so long a physical life as the low-speed plant it has superseded, provided it be possible to construct machines which do not overheat, the coils of which are efficiently and continuously supported against all stresses and vibration, and that the fire risk be removed.

If the arguments put forward in the paper are sound, machines can be constructed embracing those features, and with machines so constructed a much longer physical life may be anticipated. With dear money and expensive plant, longer physical life will be an economical necessity of the immediate future.

The latter part of the paper indicates certain specific applications of electrical power where present methods of construction should be modified to overcome successfully special conditions of working, and where it would appear that air cooling must give place to a more suitable cooling medium. Power engineering has become very largely the province of electrical engineers. If electrical plant can be made more mechanical and reliable there is every prospect of that province rapidly extending to every branch, but the fight with established practice will be strenuous. The author anticipates that the proposal to substitute water cooling for air cooling will be subjected to adverse criticism. All new ideas must of necessity be so treated; at the same time without novelty there can be no progress.

(The paper was followed by an Appendix giving a list of patents illustrating the development of turbo-generators.)

REFRACTORIES.

THE fifty-eighth meeting of the American Chemical Society included a symposium on refractories, consisting of five important papers by well-known transatlantic experts. We give abstracts of each of the papers.

"The Work of the Technical Division of the Refractories Manufacturers' Association."

This paper, by Mr. R. M. Howe, relates to work done at the Mellon Institute of Industrial Research of the University of Pittsburgh, on fireclay refractories. In the course of testing drill cores it is often found that good clay is being rejected or left in the mine because of a difference in colour, hardness, or structure. Less often, undesirable clay is used. Blending, grinding and tempering of clays are sometimes conducted separately, sometimes simultaneously. In most cases mixtures or blends are employed because these have more desirable properties than are generally found in any one clay, though many clays are used alone for firebricks. For a strong refractory product of low shrinkage, crushed firebrick bats and plastic clays are blended. Silica is sometimes added to open the structure and so increase the resistance to spalling; bauxite raises the softening-point. After these materials have been mixed, they are ground together, and in this process many of the final properties of the firebrick are imparted. The coarser grinds are generally used in producing open porous roof bricks, &c., while finer grinds are used in making dense slag-resisting and abrasion-resisting products. Fusion, slag-penetration, abrasion, spalling and re-heating tests are all of value in judging how far certain grinds and mixtures will meet the requirements of usage.

Tempering also exerts a very important influence in determining the final characteristics of a firebrick. The term tempering covers the addition of large, or small amounts of water, working for different periods of time, and the application of slight or heavy pressure during working. The effect of different amounts of water on structure of firebricks is illustrated by the following results, obtained from many briquettes:—

Water. Per Cent.	Porosity. Per Cent.	Modulus of Rupture.	Same after 20 Immersions from 1,800 deg. C. into Cold Water.	Relative Strength of Briquettes after Immersions. Per Cent.	Working Consistency.
7·5	24·0	2491	804	32·1	Very stiff mud.
9·0	20·3	6019	2776	46·2	Stiff mud.
10·0	20·6	4020	3298	82.1	Soft mud.

It is thought that these test results are typical, and that the following rules apply when sufficient pressure is used in shaping firebricks:—

1. Increasing the water content increases the strength of a firebrick until a limit is reached, after which further addition of water lowers the strength.
2. Increasing the water content decreases porosity of a firebrick until a limit is reached, after which further addition of water increases porosity.
3. An excess of water does not affect the density of a firebrick as much as an insufficient amount.

The time of pugging also plays an important part in controlling the properties of fireclay bricks. A batch of bricks, made from rapidly-pugged clay, had an average end-crushing strength of 31,667 lb. Another batch made from the same clays, pugged longer, had an end-crushing strength of 42,767 lb. Another batch (different clay) showed strengths of 36,366 lb. and 46,000 lb., respectively, for short and long pugging. The soft-mud process involves long-time tempering with a large amount of water; the dry-press involves a shorter period of working and less water; and the stiff-mud process might be considered as intermediate between these two. Each method has its advantages, and produces excellent bricks for certain uses, but one cannot state that any particular process is the best for all clays. Sometimes an easy-fired product gives the best results, but such cases are not common. During the firing a pinkish cast is sometimes developed if damp bricks are subjected to the combined action of sulphur and water. This discoloration may, therefore, indicate either an excess of impurities or the full development of the colouring effect of the usual amount.

Some clays contract rapidly at low temperatures, and after reaching a certain limit, remain constant in volume. Others continue to contract over a very wide range of temperature. A third class contracts, but very little at any temperature, being hence termed open-burning. Studies of such clays—as regards porosity after firing at different temperatures—give very useful information; they indicate to the manufacturer what treatment is necessary to remove shrinkage and give a well-fired product, and they show the consumer how the different clays will behave in service (remaining open or becoming dense at working temperatures). Such results will throw some light on the problem of spalling, which is apparently due to the vitrification of the bond clay during service, and the subsequent lower resistance to heat changes. The naturally occurring materials are limited in application, and can hardly be subjected to chemical treatment, but it is the purpose of modern manufacture to use them in the most efficient manner.

"The Selection of Refractories for Industrial Furnaces."

The author, Mr. W. F. Rochow (of the Harbison-Walker Refractories Company, Pittsburgh) stated that economy in the use of refractories is largely governed by the selection of the class of material best suited for the purpose intended, the quality of the bricks, and the design of the furnace. Good brick-laying, care in storing and handling bricks, and proper manipulation and control of the furnace, cannot be overrated. Careful study of the properties of commercial refractories and of the actual working conditions, together with practical trials, will determine the proper material to use. In some cases economies have resulted from the use of refractories whose chemical composition and physical properties would indicate that they were entirely unsuited.

Silica bricks have been used for many years in kiln linings for firing such basic materials as lime, dolomite and magnesite, the temperature not being high enough for chemical reaction. Care must be taken with kilns of this kind to avoid spalling, caused by rapid temperature changes, and to keep the temperature within the proper limits. It is sometimes economical to use a refractory of chemical character opposite to that of the products of the furnace, notwithstanding chemical action occurring between them, as in the practically exclusive use of silica in the roofs of glass tanks and pot furnaces, although subject to alkaline vapours from the glass batch. Other refractories more resistant to chemical action, have not the same combination of other desirable properties as silica. The properties of silica bricks to be considered in their use are their high thermal conductivity, mechanical strength and resistance to abrasion at furnace temperatures, thermal expansion, spalling tendency, and high softening and fusing-point. The good conductivity of silica (along with other properties) render it the best-suited material for the construction of the major portions of by-product coke ovens and other furnaces in which heat must be transferred through the refractory. Advantage is also taken of its conductivity in enamelling furnace muffles, where it is used not only for the muffle but also for the combustion chambers. In this type of furnace any danger from spalling is avoided by the proper control of the temperature on heating and cooling, when starting-up or shutting-down. Most of the expansion of silica occurs over a narrow range, and at comparatively low temperatures. By heating and cooling slowly over this critical range up to about 500 deg. C. any difficulty due to spalling is eliminated.

Notwithstanding the high thermal conductivity, the good mechanical strength of silica bricks at high temperatures makes it possible to insulate them under very difficult conditions. Unlike fireclay and magnesia refractories, there is only a narrow temperature range between the softening and fusion points of silica, and hence no deformation occurs up to the melting-point. Silica bricks used in arches and subjected to high temperatures are being insulated with such material as kieselguhr with appreciable saving. Under similar conditions the best fireclay bricks would soften gradually and eventually collapse. Where clay bricks are necessarily used, it is frequently impracticable to insulate them. Often it is possible to effect an economy by cooling rather than by insulating, and under some conditions it is necessary to provide for radiation or conduction of heat from the refractory.

Most fireclay bricks settle somewhat under a pressure of 25 lb. per square inch at 1,350 deg. C., while good silica bricks remain rigid under the same load, at 1,500 deg. C. This test is of considerable value in selecting refractories, although in most industrial applications the conditions are rarely as severe as those employed in the load test, in that only a small fraction of the brick is exposed to the intense heat of the furnace, while the remainder of the brick actually supporting any load is comparatively cold. Some bricks having a high ultimate fusion point often show greater contraction than others, of much lower refractoriness, but of higher silica content. The silicious clays expand up to certain temperatures in accordance with the relative proportions of their free silica content.

In addition to chemical analysis, and the load test, fusion test and spalling test, used for determining the quality of silica bricks, the specific gravity may be used as a criterion of the extent to which the permanent expansion should be carried in the first firing; a specific gravity of 2·38 has been suggested by D. W. Ross as the upper limit for well-fired bricks. This is accurate for most American silica bricks (made from Pennsylvanian Medina quartzite), but for others a slightly higher specific gravity is sometimes found in properly-fired bricks. Unfired silica bricks consist only of a fine-grained quartzite of high purity and 2 per cent. of lime. Upon firing, the quartzite undergoes partial inversions to other crystalline forms (cr stobalite and tridymite). These changes are accompanied by permanent volume increases, and it is desirable that this permanent expansion be attained to the maximum degree, so that no excessive, after-expansion may take place in the furnace. The specific gravities of the crystalline forms of silica are: Quartz, 2·65; tridymite, 2·270; cristobalite, 2·333; with quartz glass, 2·21.

Some quartzites invert to cristobalite and tridymite more slowly than others, giving slightly higher specific gravity to the bricks. Such bricks are practically identical with those of lower specific gravity, and when properly made do not show an appreciably greater expansion, and may be properly fired when inversion has changed the specific gravity to 2·42 or slightly lower.

Valuable results may often be obtained by studying bricks after long use. Thus in silica bricks from the roofs of open-hearth furnaces, E. Rengade found four distinct zones.

The presence of iron in any proportion lowers the fusion point of magnesia or magnesite refractories, but in quantities of from 4·5 per cent. to 8 per cent. of ferric oxide it widens the range of vitrification and develops good bonding properties at furnace temperatures. By addition of a percentage of iron oxide to American magnesite, the properties are made very similar to those of Austrian magnesite.

Magnesia bricks give excellent service, and are almost indispensable in many metallurgical operations, but unless used with due regard to their properties, unsatisfactory results may be obtained. At high temperatures, magnesia bricks are not mechanically strong nor resistant to abrasion; they expand considerably, with maximum expansion at about 1,350 deg. C. On account of this high thermal expansion the bricks have a tendency to spall when heated or cooled too rapidly.

In several applications economy has been effected by the use of metal-encased magnesia bricks in place of the regular magnesia and silica bricks in parts of the furnaces. In the manufacture of this product, rectangular or circular soft steel casings of definite gauge, open at both ends, are rammed full with a high grade of dead-burned magnesite. When properly dried the bricks are ready for use without being fired. These bricks are always laid as headers, with either open end next to the heat. No cement is used in laying the rectangular bricks, but the spaces between those of circular cross-section are filled with moistened furnace magnesite. At the temperature of the furnace in which they are used, the steel container melts back for a distance of 1 in. or 2 in. from the exposed surface, and impregnates the dead-burned magnesite which it encloses. The surface thus becomes practically jointless. Because of this monolithic surface, and the somewhat more open textures of this construction, the spalling tendency is considerably less than that of magnesia or silica bricks. The stiffening

effect of that part of the metal case which does not fuse also helps to reduce spalling to a minimum. This brick is used in the back walls, bulkheads, and gas ports of basic open-hearth furnaces, and in the side walls of electric steel-melting furnaces; it has been successfully used in a 6-ton Heroult electric furnace.

Careful attention should be paid to the design of the shape used for refractories. Difficult and intricate shapes should be avoided as much as possible. They cannot be re-pressed, are more liable to defects in workmanship, and cost more. With few exceptions they cannot be used to advantage over the standard sizes and shapes, the latter being also ordinarily available promptly when needed.

(To be continued.)

RAILWAY WHEELS AND AXLES.

By T. H. SANDERS, M.I.Mech.E.*

RAILWAY wheels and axles of the present day show numerous divergencies in essential characteristics, apart from differences of design, and it will be the aim of the author, in this paper, to describe as fully as possible the types of wheels and axles which are current in modern practice.

Fifty years ago saw what was virtually the commencement of the Steel Age. Ten-ton forgings, worked down from one steel ingot, have supplanted 10-ton forgings worked up from innumerable pieces of small iron scrap, and this, greatest of all features of bulk steel production, revolutionised the wheel and axle, by standardising in their manufacture the weldless steel tyre, and the forged steel axle, which replaced the welded and weldless types of iron tyre, and the forged iron axle. Certain quantities of weldless steel tyres, and also steel axles, were produced prior to the modern steel age, but such were manufactured from crucible steel, and their cost was prohibitive except for locomotive work.

Tyres.—Before dealing with the wheel and axle as such, it will be advantageous briefly to glance over the history of the weldless tyre, which has been such an important feature in the safety working of the world's railways. The earliest tyres were made from welded iron, as a general rule. In America, with a relatively small puddled iron industry, this practice was by no means as usual as in Europe. Car wheels were made from chilled cast-iron in the earliest days, the tyre being solid with the wheel centre, and it was not uncommon to make locomotive driving tyres of the same material, and fit them on to a cast-iron centre. Attempts were made to produce a weldless tyre, as fractures of welded tyres became more frequent with the increasing weight and speed of trains, and the first circumferentially-weldless tyres were made from iron bars, worked spirally into a ring, heated to a welding heat, and rolled to shape. These were satisfactory as far as they went, but the wear was as heavy as on the welded tyres—they were only safer. Crucible cast steel tyres were tried, cast as rings, and then rolled to finished shape. These were partially satisfactory, but owing to the final section being but little different from the cast section, fractures, both in shrinking on the wheel centre, and in service, were frequent. The next stage was to forge a crucible steel block, slot out the middle, and then expand the same to a rough circular shape, which was finally rolled to section. This was the last important step before the introduction of the present standard method.

Two modes of manufacture, differing only in the first stages, are in use. In one, "cheese" or "beehive" ingots are cast, such ingots being approximately the weight of the finished tyre. These small ingots are re-heated, flattened, and the middles punched out. They are then "becked" under a heavy steam hammer, which "becking" knocks up roughly the flange, and reduces the sectional area. The rough ring is then further heated, and placed on a rolling mill, which finishes to the profile and diameter desired. This was a popular process for use with the Bessemer converter, but with the modern introduction of high-capacity steel furnaces, the casting of such small ingots is falling into desuetude, owing to the time taken to pour the cast. This will be best appreciated by a comparison between the two processes, the converter varying from 5 tons to 10 tons capacity, and the present-day open-hearth furnaces from 30 tons to 80 tons capacity. From such large furnaces, 2 tons or 3-ton ingots are made, which are forged into rough rounds, and slabs are then cold-parted therefrom of the rough tyre weight. The continuing processes are as before sketched. The "becking" process is gradually being discarded in favour of heavy rough rolling mills, to give substantially higher production.

Axles.—The manufacture of the axle, as such, has not seriously altered over the years. It is still a forging, as it was eight years ago, but is now of steel instead of iron. Forging processes have been improved, and tools made so that it is now possible to finish the complete end of an ordinary axle at one heat. The material is first rolled down into a bloom section, cut to approximate weights, and then forged under a steam hammer. Locomotive crank axles present more interesting features as regards forging, but they are too specialised a branch to be treated at length in this paper. Many locomotive crank axles are now built up of plain pieces, forced together under the hydraulic press. Straight axles, with hollow middles—following marine shaft practice—were, for a time, produced by an American plant, but there has ceased to be any demand for this pattern, as there are not sufficient useful features present to balance up the additional cost.

* Paper read before the Sheffield Section of the Junior Institution of Engineers, on November 28, 1919.

Heat Treatment.—In present-day practice, tyres and axles are always heat-treated to remove the forging and rolling stresses. This was frequently done by putting 50 or 100 tyres, or axles, in a furnace, firing them up to 800 deg. C., or thereabouts, and letting them cool off. Another practice, with tyres, was to take them straight from the finishing rolling, and bury them in ashes to cool. Modern treatment in this direction leans to the separate and controlled heating of every tyre and axle—and many of the latter are oil-toughened from the treatment temperature.

Tests.—Before acceptance by the railway authorities, tyres and axles are subjected to stringent testing, on the basis of so many per cast, or sometimes 2 per cent. of the total quantity. The same general tests are adopted throughout Europe and America, the variation being in ultimate requirements. The chief testing variation is in the drop test: European practice insisting on a solid foundation to take the reaction of the blow of the tup on the tyre or axle, whereas American practice permits a spring foundation.

The British Standard Specification is now being increasingly adopted in this country, and other countries are following our practice. The tests required by this specification will be familiar to most. Suffice to say, that for straight locomotive and carriage and wagon axles, the selected axles must stand five blows from a ton tup, falling from varying heights, with the axle on varying centres, according to its size, without fracture occurring. Tensile test required is 35 tons to 40 tons, with 25 per cent. to 20 per cent. elongation in the standard test-piece. Crank axles have no drop test—its place is taken by a bend test-piece—and the tensile required is very similar. Tyres must stand being deflected a certain definite distance under the ton tup, deflection according to the internal diameter and thickness of the tyre. Three qualities are included, tensile requirements being:—

"B" Class: 42 tons to 48 tons, with 18 per cent. to 15 per cent. stretch.
"C" Class: 50 tons to 55 tons, with 13 per cent. to 11 per cent. stretch.
"D" Class: 56 tons to 62 tons, with 10 per cent. to 8 per cent. stretch.

A sign of the times is the recent elimination of the "A" quality, which was 35 tons to 40 tons.

Drop-testing machines for both tyres and axles have the same leading features, and while some manufacturers find separate machines desirable, others use the same drop for both purposes.

For efficient sub-division, the following groups will be taken:—

(*a*) Locomotive wheels and axles—coupled.
(*b*) Locomotive wheels and axles—tender, carrying, and bogie.
(*c*) Coaching stock wheels and axles.
(*d*) Freight stock wheels and axles.

(*a*) *Locomotive Coupled Wheels and Axles.*—The world-practice is to make these with cast steel wheel centres, and high quality steel tyres and axles. Older practice—before the days of steel castings—used to build them up from separate parts, spokes, rim and boss, and in a large wheel there would possibly be from 50 to 100 distinct pieces, all of which had to be efficiently welded. Balance weights were sometimes made solid, and sometimes bolted on to the spokes. The latter practice was objectionable, as accidents have occurred through the weight flying off. Now, of course, they are always cast complete with the wheel. European engineers favour a solid balance weight, whilst American practice frequently has only the framing of the weight cast with the spokes, the interior recess being afterwards filled with lead. This is particularly the case with small-wheeled freight engines, with heavy reciprocating parts, necessitating correspondingly heavy balances—volume for volume, lead being 50 per cent. heavier than steel. Another divergency of practice in the wheel centre occurs in the rim, American wheels generally having three gaps left in the same as cast to facilitate contraction without "drawing" at any point, whereas European centres are cast with the rim complete. Cast-iron centres have been largely used, particularly for goods engines, the spokes being of H, T or X sections, and have proved satisfactory in service.

(*b*) *Tender, Carrying and Bogie Wheels* have generally cast-steel spoke or disc centres, and steel tyres. Wooden wheels have been employed here for this purpose to a small extent, but there would not appear to be much point in this. American practice is more diverse than European for non-coupled engine wheels, and includes cast-steel centres with steel tyres, chilled iron solid wheels, and rolled steel solid wheels.

(*c*) *Coaching-Stock Wheels* in Europe are now of four distinct varieties—the wooden wheel (peculiar to this country), the rolled or cast-steel disc centre, the cast-steel spoked centre, and the forged spoke centre—all having steel tyres. There is no doubt as to the superiority of the wooden wheel for coaching stock, as it is far softer in running than any metallic wheel. Such wheels were introduced here as far back as the 'sixties, and up to comparatively recently held the monopoly of all main-line work. Modern train weights, speeds and braking appliances, however, are rather severe on a wooden centre, and it is now falling out of favour—being replaced by the rolled steel disc. Continental main-line stock generally employs the forged spoke centre or the disc, either rolled or cast. The disc centre was first made in Germany, the earliest wheel having been formed by winding forged iron bar on itself until the correct diameter was obtained, and then stamping the same to shape at a welding heat. This evolved into the balling-up of selected iron scrap, and stamping the ball into the wheel shape, but the development of steel manufacture finally ousted the iron wheel completely.

American Passenger Car Wheels used to be solid, i.e., tyre and wheel in one iron casting, chilled on the tyre tread, and inside of the flange. With increasing train weights and speeds, and the introduction of the air brake, these wheels became too dangerous for passenger service, and modern American design favours the solid rolled-steel wheel—the tyre rolled with the centre. They also employed steel-tyred rolled discs.

(*d*) *Wagon Stock* in this country runs almost entirely upon what is known as the "cold-spoke" wheel. This is a development from the spoked centre with a cast-iron boss, now entirely obsolete. Certain railways here, however, favour a cast-steel spoked centre. Continental stock runs on rolled disc, cast disc, cast-steel spoke, and "hot-spoke" forged wheels, similar to those used for carriage stock.

U.S.A. Freight Stock is nearly universally carried upon the chilled cast-iron solid wheel. It is claimed that there are over 25,000,000 in use. The whole thing has been standardised to the last point; special foundries make them in all corners of the States and Canada, and arrangements are made to take back all worn wheels at a fixed price at any foundry in the combine, and they are all in. Wheels can be bought in New York State, and sold back, in partial exchange for new wheels, in California. With the business handled in this way, it is not surprising that the chilled wheel has taken the hold it has, particularly when it is remembered that there is no Government inquiry into wrecks or the causes thereof. The first cost of the chilled iron wheel is about one-third that of the equivalent forged or cast centre plus steel-tyred wheel. Such chilled wheels are made to carry up to 25 tons per axle. A more unbreakable wheel, of solid cast steel, with a high manganese tread, is now made in large numbers of the heaviest freight cars and locomotive tenders.

Having thus reviewed world practice, a brief description will be given of each type touched upon. In this connection, it will be noted that only European and American design is referred to, for the reason that these represent two widely different schools of railway method. By American practice is meant that of the United States of America, Canada and Mexico; and by European, that of Great Britain, France, Belgium and Germany. The outer group following American practice is not very large, chiefly being confined to certain Central and South American States. Practically all other countries follow European practice.

Cast-Steel Wheels.—There is little to be said in connection with the manufacture of these—they are straight steel castings of about 30-ton tensile steel, and of any design that may be fancied—spoke, disc or solid-tyred. When the latter, the wheels should be turned or ground on tread, with a view to discovering any unsoundness. Tensile tests are generally taken to represent the centres, and it is sometimes specified that every wheel shall be dropped from 5 ft. high, or thereabouts. Cast-steel wheels suffer from the usual feature of cast steel, namely, blowholes and sponginess, but a good electric welding plant will counterbalance such defects.

A cast-steel solid wheel deserving special mention is made in the United States of America. It has a high manganese tread, and a soft steel centre, and is manufactured by pouring into a revolving mould first the high manganese steel to a certain definite weight, and then the soft steel, which forms the middle of the wheel. The centrifugal force on the first metal, generated by the revolving mould, throws outwards the high manganese steel to form the tread. Wheels of this type are ground with special machinery to obtain a good running surface.

Wooden Wheels.—Such wheels represent the perfection of wheel manufacture. The wood employed is invariably teak, and 16 segments make up the wheel. A forged or cast-steel boss, with a plat, take securing bolts which go through the segments, and at the tyre circumference bolts go through the retaining (Mansell) rings and segments. The tyre is generally forced on by hydraulic pressure, and sometimes heated and shrunk on, the tyre being rapidly cooled by water, so as to avoid the charring of the wood. This latter is not, however, considered good practice. When made completely up, and mounted on the axle, the tyres are most carefully turned to exact diameter, and the complete wheel and axle set is then balanced. This is done to obtain perfect running, as if one wheel is slightly heavy at any particular point—this is tending to lift at high speeds, and spoil the smooth running of the vehicle. The balancing is done by mounting each pair of wheels and axle on a spring frame, and running them at 60 m.p.h. to 70 m.p.h. Few pairs balance exactly on the first run, and it may be necessary to stop them at 40 m.p.h. and screw on balance weights. The running is then continued, and balance weights screwed on and adjusted, until absolute smoothness of running and absence of jump proclaims that the set is perfect.

The chief difficulty found with wooden wheels is the damage to the bolt holes in the wood caused by the action of the brakes. Many devices have been used to minimise this, the aim being always to obtain more bearing surface of the wood on the bolts.

Two side lines of wooden wheels are in use, one having four iron arms from the boss to the tyre, with the segmental spaces in between wood-filled. The other has an iron disc centre of special design, and between the rim of this and the bore of the tyre teak blocks are fitted. It is known as a "cushioned wheel."

Forged "Hot-Spoke" Wheels.—This is one of the most useful types of wheel, as it can be employed for carriage or wagon stock, and is practically everlasting in service. There are two chief types, the single-arm and the double-arm. The latter is now most in favour, cast-steel wheels of almost identical design replacing the forged single-spoke.

The earliest type of the double-arm wheel had the spoke rolled with special thick-shaped ends, as well as

a thick "back," or middle length. These spokes were bent to triangular form, which caused the shaped ends to close nearly up when the seven, eight or nine spokes, as the case may have been, were assembled. The spokes thus assembled were got to a welding heat, and thick iron washers, also at a welding heat, were hammered on to form the boss. A later development substituted plain-ended spokes, with a boss lump made out of best selected wrought-iron scrap, and a hydraulic press instead of a steam hammer. Practically all such wheels to-day are made in this manner. For a standard-gauge wheel centre the pressure necessary to form a sound boss is about 500 tons.

The single-arm wheel is made in divers ways—none of them as simple as the double arm, and all entailing more welds at important points. The chief difference between the two types is that, whereas in the single arm there is a weld between the rim and the spoke, in the double arm they are in one piece. The gap between the two corners of adjacent spokes is filled by a glut, pressed in hot.

Forged "Cold-Spoke" Wheels.—This is the standard British wagon wheel, and it is also used to some extent abroad, but is not so much favoured outside this country as the "hot-spoke." It is not a suitable wheel for putting under stock fitted with automatic brakes, unless there is a minimum of braking. For stock such as is run in these islands, however, which is fitted with hand brakes only, and on which no prospect appears of the automatic brake, there is everything to recommend the "cold-spoke" wheel, as it will last as long as the wagon, and is a very safe type.

Spokes are rolled similarly to those for "hot-spoke" wheels, and bent in the same machine. These spokes are then assembled in the press tool, and a wrought-iron boss lump, at welding heat, is squeezed round. More pressure is required to make a satisfactory "cold-spoke" wheel than a similar-sized "hot-spoke" and heavy wheels of the former pattern should have about 1,000 tons.

Cast-Iron Boss Wheels.—These were largely made here up to ten years ago, but the process had been dropped long before this on the Continent, and is now obsolete in England. Spokes were rolled as for the two types of forged wheel just described, assembled in a frame, and the molten metal cast round. The dangers of such wheels lay, of course, in the possible cracking of the boss if "high-strung" in the pressing on, although many thousands have been running for thirty years and more.

Rolled Steel Disc Wheels.—For the manufacture of these, soft steel is cast into small cheeses or ingots of the approximate wheel weight, and of a rough shape. Alternatively, blanks are cut from heavier ingots, or rolled rounds. Successive heatings and pressings under heavy hydraulic presses (up to 8,000 tons) work the blank out into a shape convenient for the special rolling mill. This mill then rolls out the web thickness to whatever is required, obtaining, at the same time, the correct diameter. A further pressing is then given to obtain the necessary buckle or corrugation, which gives the boss off-sets, and a certain amount of stiffness to the disc.

This type of wheel centre was first cultivated on the Continent, and was very largely used there many years before any plant was put down here to deal with its manufacture. There are now three plants in this country, with prospects of more. So far, however, it is extremely doubtful whether British manufacturers can successfully compete for price with the Continental makers, as they have had the advantage of several years additional experience in cheap production.

The steel used for these rolled wheel centres is between 28 tons and 32 tons tensile strength, and the centres are frequently tested by being dished cold.

Rolled Steel Solid Wheels.—The fact of the tyre being solid with the wheel centre entails a harder quality of steel being used than is the case with the foregoing type, as 30-ton steel is not a very wearable variety for the rolling surface of a wheel. For the solid wheel, the steel is generally between 35 tons and 40 tons, and sometimes the tyre surface is treated, with a view to giving a hardening effect.

Apart from the quality of the steel involved, the general process is similar to that for the manufacture of the rolled wheel centre. Both these types involve very heavy plant and machinery for their high-speed production. To balance the manufacturing cost entailed by the heavy plant outlay, everything must be specialised (and the wheels produced standardised, if possible), and laid out for a high output; an American plant working on the ingot-slab-blank-wheel basis, having, for instance, a manufacturing capacity of 700 wheels per day. This represents about 210 tons of finished material, which would require the whole output of three 50-ton steel furnaces.

Cast-Iron Solid Wheels.—The production of these wheels is confined almost entirely to the United States of America and Canada, only two plants in this country doing anything in this direction, as hitherto, there has been no demand here, for home purposes, and very little for the export trade. An idea of the manufacturing magnitude of this wheel will best be appreciated by realising the fact that the 50 plants in operation across the Atlantic have a total capacity of 20,000 wheels per day—say, 6,000,000 per annum. The combine guarantee an average life of five years per wheel, and will replace free of charge any wheel failing within this period. They claim, however, that quantities of wheels remain in service up to double this time. On a general basis, of the number of wheels running and the capacity of the foundries, it would not appear that the general life is much over five years. The cost of such wheels at the present day, compared with the forged tyred, or the forged solid wheel, makes them an attractive proposition, and it is to be feared that many of the countries which, up to the war, had standardised along European lines, will now revert to American practice in this direction.

The original "double-plate" wheel was first designed in 1838, and it has evolved along the same lines to the present day, the increases in car capacities being balanced by corresponding increases in wheel weights. Standardisation of wheel diameters and axle sizes has been one feature which has substantially tended towards the economical production of the chilled wheel. Four standard axle sizes are involved for all classes of stock—freight cars, passenger cars, and locomotive tenders, and 10 types of wheel, varying in weight from 625 lb. to 950 lb., for 4½ in. by 8 in. and 6 in. by 11 in. journals, respectively, are arranged to cover all conditions of service, regard being paid to type of vehicle and general area of operation, as stock, to be worked regularly over mountain divisions, with consequent heavy braking, demands a heavier type of wheel than corresponding stock running over normal roads.

Careful attention is given to the selection of the metal, and a subsequent annealing for some days of every wheel, but chiefest of all, very great care has been used in the design, which has been modified from time to time, as experience has suggested. The chief danger point in the wheel lies in the flange, as it is not possible to stiffen this seriously owing to the standard distance of check rails from the running rail of 1⅞ in., which is a world standard on the 4-ft. 8½-in. gauge and over. The modern high capacity freight car in the United States of America entails five times the amount of flange thrust to change its direction, as did the cars of the early days of rail-roading, and the maximum effort which can be made to cope with this has been an increase of ¼ in. on the original flange thickness of 1½ in., at the gauging point. The resultant is increased flange breakages, with potential derailments.

One per cent. of wheels are subjected to a drop test, the wheel being laid horizontally upon three supports, and a tup of 140 lb. weight allowed to fall freely on the boss from a height of 12 ft. The number of blows is from 20 upwards, according to the weight of the wheel, and it must withstand these without fracture into distinct parts.

One per cent. are subjected to a "thermal test," molten metal being poured round the tread. Two minutes after the pouring has ceased, the wheel is examined, and should it have broken, or be found with any cracks from plate to tread, the lot is rejected.

Solid-cast steel wheels, or forged steel wheels, when worn to the gauge limits, frequently have the tyre portion turned off, and are then fitted with rolled steel tyres. Such course of action is never carried out with the cast-iron wheel, which is virtually done for when the chill is worn through.

In a general sort of way, the various world types of wheels have now been reviewed, and the remainder of the paper will be devoted to certain essential details.

Tyre Fastenings.—It is obvious that unless an efficient securing means is employed to attach the rolled tyre firmly to the wheel centre, in a two-part wheel, an element of risk is encountered. The solid wheel advocates, with a certain show of reason, base their arguments on the attachable, and, to their minds, detachable, tyre.

The earliest fastening consisted merely of a rivet through the wheel rim and the tyre. Accidents were continually happening in those early days through welded tyres breaking, and then stripping off the wheel. The first really sound fastening was introduced concurrently with the wooden wheel in the 'sixties, namely, the "Mansell" type, with two retaining rings. No other type can be used with wooden wheels, and it is also largely employed for forged spoke wheels. It is a very strong and solid fastening, and also very expensive, compared with later developments, and with the impending decease of the wooden wheel, and the present high prices of all things, will ultimately fade away.

Numerous cheaper and simpler retaining rings are now employed—in this country very largely the "Gibson." The retention and fixing of all modern rings turns upon the tyre closing down firmly on them. This is done immediately after the tyre has shrunk tightly on to the centre, either by means of a small power hammer, or a hydraulic rolling machine.

The original idea of a ring was, as has been pointed out, to keep the tyre on the wheel should it fracture, but breakages of tyres to-day are not worth counting. The ring, however, provides one of the simplest forms of securing a tyre, and is the only practicable type for rolled disc centres.

Many railways prefer a set screw fastening, some having the screw tapped into the rim and tyre, others plain in the rim and tapped in the tyre, and others tapped in the rim and plain in the tyre. It is a moot point whether a set screw weakens a tyre sufficiently to cause fracture, as is sometimes argued. It is more in favour for locomotive work than any other form of fastening. One advantage attaches to a set screw, namely, the tyre cannot rotate on the centre, as sometimes happens if the shrinkage allowance has been light, and braking causes expansion. It is a very usual practice, with ringed wheels on braked stock, to introduce locking pieces between the tyre and the rim of the wheel to prevent such rotation.

It is possible to secure the tyre to the centre with a shrink fit only, a small lip on the inside of the bore expanding sufficiently when the tyre is heated to allow the centre to drop in, the subsequent cooling of the tyre bringing back the lip over the wheel.

Axles.—The size of the axle is determined primarily by the size of the journal. Many decades of experience have dictated a standard figure of bearing pressure, and all railways throughout the world are employing the same designing factor, of 250 lb. to 350 lb. per square inch of nominal bearing surface. A 12-ton wagon, tare 6¾ tons capacity 12 tons, total 18¾ tons, less 1½ tons for wheels and axles, gives 17 tons on four journals, or 4¼ tons per journal. These are 4½ in. by 9 in., total 38½ sq. in. Pressure per square inch, nominal, 250 lb. A locomotive driving axle, journals 8 in. by 9 in., carries 16 tons, 8 tons per journal, excluding weight of wheels and axle, or 250 lb. per square inch. Journals should be increased in length rather than diameter, to obtain greater bearing weights, as an increase in the latter means a higher superficial speed, and consequently a higher frictional resistance. The limit of length of outside journals is, however, determined by the loading gauge, which, in European practice, confines them to a maximum of about 10 in. American practice loads up to 350 lb. per square inch, nominal, and, furthermore, is now employing journals 12 in. long.

The expression "nominal pressure" is used as, in actual practice, the whole calculated bearing area of the journal is not employed. Obviously, the most useful locus for a unit weight of bearing metal is the top of the journal, and railway axle-box bearings do not, as a rule, come down within some distance of the centre line of the axle. The angle subtended by the bearing brass is anything between 60 deg. and 120 deg., according to the standard practice on various lines. Taking the actual bearing area, therefore, the pressures are higher than the nominal—being actually 400 lb. and 350 lb. in the two cases quoted for the wagon and locomotive respectively, as against 250 lb. worked out on the full journal size.

Many designs of locomotives have been made with four bearings per driving axle, and others with three, owing to limitation of length between the insides of the frames, and modern examples of this type have brought the weight per square inch down to under 200 lb. nominal. It is doubtful, however, as to whether such practice justifies its expense, as double frames, or a middle auxiliary frame, are necessary, and the majority of locomotives, working at 250 lb. to 300 lb. nominal, give very little trouble. The whole thing turns on the lubrication facilities embodied in the axle-box design, which is outside the scope of this paper.

Except for locomotive work, axles are generally left black between the wheel seats, and forged with taper middles, the idea being to give them a certain amount of flexibility. This was perhaps achieved in the days of iron axles with 4-in. middles. It is a nice point to-day, however, as to which is likely to prove the more flexible, a 6-in. steel axle or modern permanent-way. Track, as universally laid, is elastic. Early railway engineers made it absolutely rigid, and found, in consequence, extremely hard running and continual breakages of all running gear. With modern steel development, and high-capacity rolling mills, rolled bar-axles, with journals and wheel seats machined from the solid, should prove more economical, and quite as efficient as the general forged variety.

For high-class carriage stock, such as employs wooden wheels, it is, of course, necessary to turn the axles all over to obtain the correct balancing, as the average forged axle is not impressive as regards accuracy of the middle part.

Breakages of axles are very rare, the majority being locomotive crank axles. Ordinary straight axles on locomotive service are generally guaranteed for 200,000 miles run. The heaviest service employing straight axles is undoubtedly the electric railway, as the low centre of gravity of the motor bogies, coanbined with the unspring-borne motor weight which takes its bearing on the axle, gives very severe operating conditions. With railways necessitating the employment of motor coaches, this state of affairs is in permanence; but electric locomotive development has now removed itself from the axle-borne motor design, and taken to steam practice, the heavy driving motors being mounted on the frames, all the weight being thus spring borne, and driving the running wheels by couplings and connecting rods.

The bulk of axles (excluding crank axles) that fail, break at the back of the wheel seat, which receives the severest shocks in running, owing to the leverage from the flange. Generally some small tool mark or defect forms the commencement of the break, and it is of great importance that the axle is smoothly finished behind the wheel. In the design of axles, special care must be taken to avoid square corners in altering the diameters, good radii being essential at all such points.

Fixing of Wheels on Axles.—All classes of wheels are now pressed on to their axles by hydraulic pressure. The general rule is to allow 10 tons to 12 tons per inch of wheel-seat diameter, a 6-in. wheel seat, for example, would be permitted a forcing-on pressure of 60 tons to 72 tons. Keyways in wheels are completely obsolete, except for locomotive driving and coupled wheels, where they act more as a position register for the crank-pin displacements, than as securing devices. The pressing of wheels on to their axles is the most important item involved in their manufacture, as serious results are likely to occur should a wheel move in service, as has happened when the putting on pressure has been deficient. The running shocks against check rails or frogs always tend to move a wheel, and if put on light such movement will eventually occur, and lead to a derailment. It is compulsory by specification for all presses to be fitted with automatic recording gear, which registers every wheel pressure, and, in addition, for coaching stock in Great Britain, every wheel is submitted to a drawback, or reverse pressure, of 50 tons. In earlier days, when wheel fits were less reliable, keys were always depended upon for securing purposes, but the necessary axle slot and wheel-boss slot, were danger points, leading to many breakages, which facts have ultimately resulted in the complete banishment of the key.

YACHT BUILT AT PORTSMOUTH.—In the paragraph under the above title on page 14 *ante*, the name of Messrs. Vosper and Co., Limited, Portsmouth, the builders of the yacht referred to, was omitted by inadvertence.